SCHOOL TECHNOLOGY SERIES

WORKSHOP PRACTICE

A TEXTBOOK FOR TECHNICAL SCHOOLS

PART TWO

NATIONAL COUNCIL OF EDUCATIONAL RESEARCH AND TRAINING

WORKSHOP PRACTICE

A TEXTBOOK FOR TECHNICAL SCHOOLS

SCHOOL TECHNOLOGY SERIES

WORKSHOP PRACTICE

A TEXTBOOK FOR TECHNICAL SCHOOLS

3357

B. B. Mukherjee
S. C. Das

Part 2

NATIONAL COUNCIL OF EDUCATIONAL RESEARCH AND TRAINING

June 1968
Jyaistha 1890

Rs. 4.80

Published at the Publication Unit, B 31 Maharani Bagh, New Delhi 14 by P.N. Natu, Secretary, National Council of Educational Research and Training, and printed at Indraprastha Press, (CBT), Nehru House, Bahadur Shah Zafar Marg, New Delhi-1.

Foreword

IT IS A TRUISM that we live in an age of technology. Our four successive Five-Year Plans are all directed towards the development of a technological society. To this end, we have to train a multitude of technicians who will set up plants, and design and produce machines, tools and implements to bring to fruition the well-considered Plans of an informed leadership.

The National Council of Educational Research and Training is particularly concerned today with education at school level. Technology is one of the fifteen subject-fields in which the National Council, on the advice of its Central Committee on Educational Literature, is bringing out textbooks. In agreement with public feeling and recent recommendations of the Education Commission, the Council is producing educational material for vocationalized secondary schools. The present publication on Workshop Practice is an earnest of its plan of work to provide the schools with model textbooks. This is one of the four textbooks that have been prepared under the direction of Prof. K.B. Menon, Head of the Department of Electrical Engineering, Indian Institute of Technology, Kharagpur. The other three books in the series are: (i) *Engineering Drawing*, (ii) *Elements of Electrical Engineering*, and (iii) *Elements of Mechanical Engineering*.

Workshop Practice is an introductory book for students in the higher classes of Indian secondary schools, who offer engineering as an elective subject and for students of specialized technical schools. The book will also be useful in the earlier stages of the polytechnic diploma course. The aim of the book is to present an over-all view of the major areas in the subject without entering into specialized details required for advanced studies. Its purpose is to develop in the students an understanding of the basic principles of workshop practice. The text is in simple English and all technical terms have been defined with clarity.

The National Council wishes to thank the authors of the book, Shri B.B. Mukherjee and Prof. S.C. Das for having undertaken this work, and Prof. K.B. Menon who has directed the whole project of textbooks in technology. The Council is also grateful to Dr. S. R. Sen Gupta, Director, Indian Institute of

Technology, Kharagpur, for the facilities provided for the completion of the project.

The National Council hopes that all students of technology at secondary level and students of specialized technical schools and polytechnics will benefit from this book. Suggestions from teachers, and others interested in Workshop Practice are welcome, and will be considered when the book is revised.

L.S. Chandrakant

Preface

IN THIS BOOK, an attempt has been made to explain to the beginner the basic principles of various trades and to discuss the application of these principles in relation to human needs. It is a rather difficult task to explain the technicalities of the trades in a language which students at the secondary level would find easy to understand. There are certain concepts which seem to elude precise analysis in simple language, for simplification sometimes leads to inaccuracy. In such cases, a compromise has been resorted to but generally the method of direct conversation and business-like language has been used. In order to keep the book within certain limits it was necessary to be brief on a number of points. However, suitable diagrams have been supplied where long explanatory notes were not feasible.

The reader is not meant to get the impression that every possible problem in the various trades has been discussed in this book. The intention is rather to guide the beginner through the workshops and give him the information he will *actually need* while he *works*. We have tried to explain and describe things in a way that would help the beginner to form a clear idea of his job so that he is not reduced to a mechanic who blindly follows some rules and sequences of operation, but shapes into an intelligent workman who knows not only the *how* but also the *why* of the operations. A practical approach has therefore been maintained, but the objective has been to give the beginner a solid grounding. In some chapters, information has been provided about the sources of raw material and the location of steel and other plants and of power-stations that have been established by the Government of India during the various Plan periods. This has been done with a view to improving our young students' knowledge of the industrial development of the country. This information may incidentally help them to choose their careers and may equip them better for the choice they make.

We found some information, diagrams and photographs in certain books (mentioned in the Acknowledgements) which suited our requirements exactly and therefore borrowed them without wasting time in trying to be a hundred per cent original. Our debt to the authors and publishers of these titles has been acknowledged separately.

Our thanks go to the organizations and individuals who assisted in preparing this book. The South Eastern Railway Workshop authorities helped us with a few photographs of wood-working saws. The authorities of the Indian Institute of Technology, Kharagpur, were generous enough to place at our disposal various facilities required in the preparation of this book. Special mention must also be made of the services rendered by the following members of the staff of the Institute: Shri S. G. Ray for typing the script, Shri P. Chatterjee for taking the photographs and making the prints, Shri P. Banerjee, Shri C.K. Ghosh and Shri A.P. Bose for preparing the drawings, and lastly, Shri D. Sen, Lecturer in Humanities, for editing the script. We would also like to acknowledge the advice given in the initial stages by Shri D. N. Sarbadhikary, formerly Lecturer in Engineering at the Hijli High School, West Bengal.

B. B. Mukherjee
S. C. Das

Acknowledgements

The authors wish to acknowledge their debt to the authors and publishers of the following books which have been consulted and from which diagrams and photographs have been reproduced in the book.

Figs. 7.7, 7.51	Chapman, W.A.J. *Workshop Technology*. Edward Arnold (Publishers) Ltd. 1954
Figs. 7.1, 7.50, 7.53, 7.55	*Starret Tools*. 2nd Ed. Catalogue No. 27. Athol-Massachusetts, U.S.A: L.S. Starret Company
Figs. 8.2, 8.5, 8.28, 8.30	Chapman, W.A.J. *Workshop Technology*. Edward Arnold (Publishers) Ltd. 1954
Figs. 8.13, 8.22, 8.27	Boston, O.W. *Metal Processing*. 2nd Edition, New York: John Wiley & Sons, Inc., 1958
Figs. 12.1, 12.5, 12.6, 12.15, 12.22, 12.24, 12.29, 12.30, 12.31a,b, 12.32a,b,c, 12.33a,b, 12.42, 12.45	Dunwoody, T. *Practical Electrical Wiring*
Figs. 12.14, 12.17, 12.18, 12.19, 12.26, 12.35, 12.41, 12.43, 12.46	Cowley, H.H. *Modern Electrical Wiring*
Figs. 12.8, 12.9	Hurbert Charles 1. *Preventive Maintenance of Electrical Equipment*. Ny: McGraw Hill Book Co.
Figs. 12.2, 12.3, 12.4, 12.7, 12.10, 12.11, 12.12, 12.13, 12.23, 12.27, 12.28, 12.34a,b,c, 12.36, 12.39, 12.40	Urwin, C.R. (General Editor). *Electrical Wiring, Theory and Practice for Practical Wiremen, Engineers and Students*
	Watts, J. L. *Electrical Maintenance and Repairs*. London: Hume Press Ltd.
	Vinogradov, N. *Industrial Electrician—A Manual of Repair and Installation*. Moscow: Foreign Languages Publishing House

The authors also wish to express their gratitude to the following organizations that supplied useful material for inclusion in this book.

Chesterman & Co. Ltd., James, Pomona St., Eccleshall Road, Sheffield-11 (U.K.)
The Brooks Tool Manufacturing Co. Ltd., Warwick Road, Greet, Birmingham,11 (U.K.)
Town Frederick & Sons. Ltd., Mile Cross Engineering Works, Gibbet St. Halifox (U.K.)
Archdale, James & Co. Ltd., Blackpole Work, Worchestor, Worchestor (U.K.)
Brookes, A & Sons (Machine Tools) Ltd., Derby Road, Kegworth, NR. Derby, Kegworth—256 (U.K.)

Contents

CHAPTER 7

Fitting

7.1. Introduction

Fiittng covers a very wide area in metal working. Designers design an engineering product that is expected to function according to the requirements of the users. To function properly, all parts of the product must be manufactured correctly and assembled properly. These are the two most important aspects of a manufacturing process.

The correct manufacturing of components requires careful and skilful use of machine tools and hand tools. This judgement and skill can be acquired only by practice and. experience. Operations like turning, shaping, milling, sawing, chipping, filing, scraping, grinding, etc,, may be necessary to make parts fit properly. When suitable components are produced, they need to be put together to make a complete product. This is called assembling or fitting. Assembling can be of two types. In the first, the parts are tightly joined, and in the second the parts are joined in such a manner as to permit relative motions. Producing such suitable components by various metal-working processes and assembling them is the fitter's job.

7.2. Fitters of Different Trades

Fitting operation is required in different types of work in industry. Fitters are accordingly classified as:

(a) MAINTENANCE FITTER. A maintenance fitter dismantles machine and equipment, repairs or replaces the defective or wornout parts and assembles the machine and equipment again, so that they may function properly.

(b) ERECTION FITTER. An erection fitter erects or constructs certain structures or equipment in the field.

(c) PLUMBER OR PIPE FITTER. The construction and maintenance of gas, water and steam-pipe lines, constitute the work of a plumber or pipe fitter.

(d) ELECTRIC FITTER. An electrician or electric fitter is expected to repair electrical equipment and lay house-wiring.

(e) ASSEMBLER. An assembler assembles either parts or complete products. Besides, he may work in lines or bays in the case of chain production. He may work either alone or, more frequently, in a group, to assemble new big products such as machine tools, railway coaches, etc.

(f) TOOL AND DIE-MAKER. A tool and die-maker works in the tool room of an industry. The tool room is a place where skilled operators work with precision machine tools to manufacture

tools and dies for production shops. He must therefore be a very good precision worker and skilled fitter.

Some fitters are also classified according to the trade and the type of product they are handling, such as automobile fitter, aircraft fitter, and refrigeration fitter. All are expert maintenance men in their particular trades.

Sometimes, distinction is made between mechanics and fitters. The former are machine men and the latter are bench men working with hand tools and vices.

Fig. 7.1 Tools for measurement

7.3. Types of Fitting

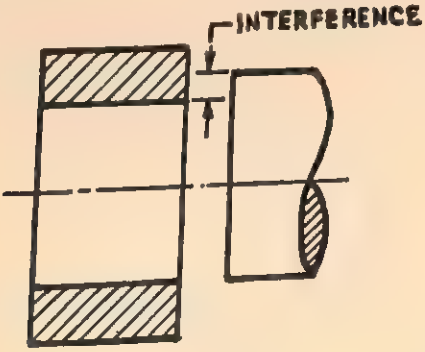
A fitter has to fit and assemble. The word 'fit' has a great significance in engineering and technology. In simple terms, a joint between two parts is called a fit. These two parts are called mating parts. The pair may be a hole and a shaft, a tongue and a groove, a slide and a guide, a screw and a nut, and so on. The outer one of the pair is called the female part and the inner, the male part. The screw or shaft is known as the male part or plug, the hole or the nut is the female part. This type of fitting is called male and female fitting.

The plug and the hole is the simplest case of fitting. The fit in this case may be of different types. It may be very light, tight, sliding or very loose. The nature of fit depends on the dimensions of the male and the female parts. In metal work, fitting is broadly classified as:

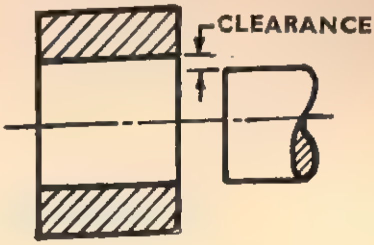
I. Interference fit (Fig. 7.2a)	(a)	shrink fit
	(b)	force fit
	(c)	drive fit
II. Clearance fit (Fig. 7.2b)	(d)	push fit
	(e)	running fit
III. Transitional fit		

In the first three cases, (a), (b) and (c), the male part is made larger in size than the female part. This type of fit is called the interference fit. In (d) and (e), the size of the male part is smaller than that of the female part. These are cases of the clearance fit. The magnitude of the difference between the sizes of the two parts of a pair characterises the nature and degree of a fit.

There is a third type of fit known as the transitional fit. A particular dimension of similar components manufactured under



a. Interference fit



b. Clearance fit

Fig. 7.2

the same conditions does not remain constant, however precise a machine tool may be, and whatever precaution an operator may take. In the case of a very close fit between a pair of mating parts, a situation may arise in which either the dimensions of the male part are greater than those of the female part or vice versa. The nature of fitting varies accordingly in such a case. These are the cases of transitional fits.

(a) *Shrink fit:* As the name indicates, this fit is obtained by heating the ring, putting the mating parts together and allowing the ring to shrink. The shaft diameter is made bigger than the hole diameter. The difference depends on the co-efficient of expansion and the strength of the material, the temperature to which the ring to be heated and the nature of tightness required. In this case, the gripping pressure is about three times that in the case of the force fit. *Example*—a gear shrunk to a shaft.

(b) *Force fit:* In this case, too, the shaft diameter is bigger than the hole diameter. The parts are fitted with the help of a powerful press. The difference between the sizes of the shaft and of the hole should be such that the shaft can be pressed in and the fit may take place by the elastic and plastic deformation of the parts. *Example*—railway wheels pressed and fitted on the axles.

(c) *Drive fit:* It is similar to the force fit save that the amount of interference here is less. The pair is assembled by striking only. *Example*—a dowel pin fitted in a hole.

(d) *Push fit:* In this case, the shaft diameter is less than the hole diameter, but the difference is very small. This fit is used in precision assembly of parts.

(e) *Running fit:* Here the shaft diameter is less than the hole diameter, but the clearance is wider than in the push fit. The mating parts are allowed a relative movement, either sliding or rotating. *Examples*—the carriage sliding on a lathe bed, a spindle rotating on a bearing. In this fit some lubricant is always used to obtain low friction and longer life.

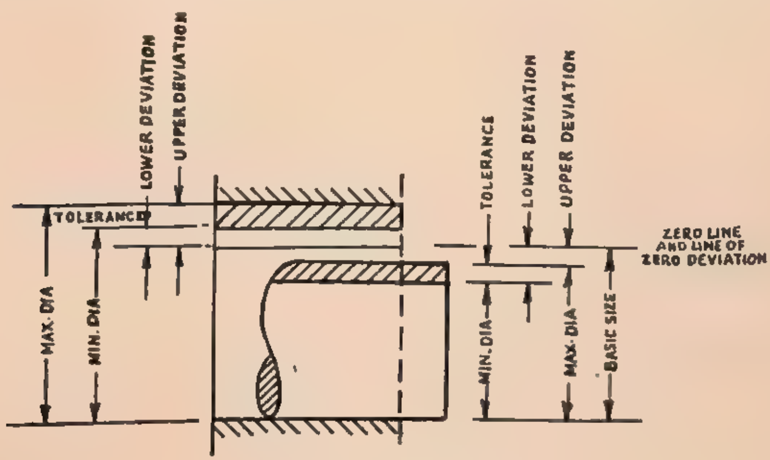


Fig. 7.3 Nomenclature in fits

Nominal size of a part is the dimension by which it is referred to conveniently. *Basic size* of a part is the dimension in relation to which all limits of variation of dimensions are expressed. The nominal size and the basic size of a part are often the same. *Actual size* is the actual dimension of a part as measured.

Limits are the two extreme possib

dimensions of a part, there being a high limit and a low limit. High limit refers to the largest dimension and low limit refers to the lowest dimension permissible for the size of a job.

Tolerance on a dimension is the difference between the high limit and the low limit. It is the variation in dimensions tolerated in a product. Tolerance varies according to the grades of work.

Allowance is an intentional difference between the shaft dimension and the hole dimension of any type of fit. The maximum allowance is the difference between the maximum hole size and the minimum shaft size, and the minimum allowance is the difference between the minimum hole size and the maximum shaft size. When allowance is positive, it is called clearance, and when negative, it is called interference.

7.4. Tools and Equipment of a Fitting Shop

A tool is any instrument or appliance used by a workman in wood working, metal working, erection, assembling and similar other processes. Development of tools indicates the growth of civilization. In ancient times, tools were crude and knives, carving tools, striking tools, etc., were made of stone. These have been gradually refined and are now made of stronger metal. The life of tools, their efficiency and the variety of uses to which they are put have since increased in a very great measure.

7.5. Classification of Tools

Tools used only with hands are called hand tools. But a powered equipment can also serve the purpose of a tool and is called a machine tool. However, in certain cases, a hand tool is also powered, electrically or pneumatically, such as an electric hand drill, a pneumatic screw driver or chisel, a power hacksaw, etc. So, broadly, tools may be classified as hand tools and machine tools.

Tools may also be classified according to work material. They may be wood working tools or metal working tools. Again, they may also be classified according to the method or nature of metal working, such as fitting tools, foundry tools, forging tools, welding tools, measuring tools and so on. Even in one single trade, tools are classified according to the nature of their use. This will be discussed later in this chapter.

GENERAL CHARACTERISTICS OF HAND TOOLS

The main purpose of using tools is to perform a job efficiently and with little effort. So tools should be designed and manufactured accordingly. A hand tool should (a) work properly, (b) be easy to handle, (c) have durability and (d) be of standard specification.

To attain these objectives, hand tool designers and manufacturers take special care to decide the shape and size, to select material and recommend heat treatment. The shape and size of a tool depends on the type of work for which it is used. A screw driver is used for tightening or opening screws. As such, its head should fit the slot on the heads of screws. Since it is rotated by hand, the handle should be of such a size as to fit the grip of a person using it. For proper gripping and transmission of effort, the handle should have serrations and a round or any other suitable shape. For the convenience of constant use, the handle has to be light and made of wood. The material of the screw driver should be tough steel so that it may have sufficient strength to bear and turn the screws inside wood or screwed hole and to tighten properly. Its tip should be hard. If it is soft, it will get spoiled quickly. On the other hand, if it is too hard, it will

break. The length of the screw driver is in accordance with the sizes of the screws for which it is used and the physiology of a man. If it is to be used for electric work, the handle should be made of insulated material. If it is to be used for precise instruments with fingers only, the size and the material of the handle should conform to the necessities of the situation. Its size and shape are standardised, because it will be used for screws which are manufactured under certain standard specifications.

From this example of a suitable screw driver, it is seen that the size, the shape, the material and the nature of heat treatment of a tool are determined by the requirements of efficient use and longer life. The limitations imposed by the general physiology of a man is another determining factor. In case of all hand tools and, indeed, for all engineering products, the above considerations hold good and decide the characteristics of the tool. There is another class of tools which are used as measuring instruments. Accuracy (preciseness) is another important characteristic of this class of tools besides what has already been mentioned.

7.6. Fitting Tools

Fitting jobs vary according to the trade, industry, product and the type of work done. Hand tools also vary according to the requirements of the fitter in doing his job. The mechanic kit of an automobile fitter is different from that of a bench fitter or refrigeration fitter. However, there is a very large common ground too. The fitting tools most commonly used by a bench fitter can be listed as:

(a) Gripping tools (b) Striking tools
(c) Cutting tools (d) Assembly tools
(e) Marking tools (f) Measuring tools

GRIPPING TOOLS

Objective: To hold an object properly and securely so that it can be worked on.

Feature: The tool must have jaws which can be closed to grip the object. The jaws are generally actuated by screw and nut mechanism. The number of jaws should be at least two; for round objects the number may be three. The jaws should be hard, and should not give way under clamping pressure. The sizes must suit small, medium and heavy jobs.

Type:

(a) Bench vice (b) Machine vice
(c) Hand vice (d) Pin vice
(e) C-clamps (f) Tool maker's clamps

(a) *Bench vice :* This gripping tool is extensively used by a bench fitter to hold his work (Fig. 7.4). The vice consists

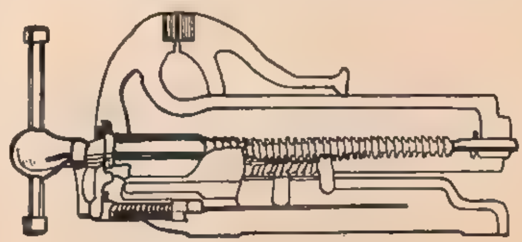


Fig. 7.4 Bench vice

of a cast iron or steel body with one of the jaws fixed on it. The other jaw is fixed on a sliding part which slides through the square hole inside the vice body. The motion of the sliding jaw is given by a screw and nut arrangement, as shown in Fig. 7.4. The jaws are hardened and serrated for better grip and are fixed with screws on the body and the sliding part. The clamping screw has a lever at its head for rotation and for exerting clamping force for gripping. The lever rod can slide through the hole at the head of the screw for easy manipulation.

The vice is fixed on the edge of a fitter's table. The fixed jaw projects slightly from the edge of the table so that long objects can be gripped vertically without any interference from the table. The body of the bench vice sometimes rests on another base and has the provision for rotation about a vertical axis. The vice may have to resist impact loads of hammering, and should be made of steel, either forged or cast. When finished jobs are held in a vice, jaw caps of softer metal like copper or brass are used so that there are no jaw marks on the finished job. Buttress threads are used in the screw and nut of a vice as these can take more load than other types of thread. The details of the buttress thread will be discussed under 'Thread Manufacture'. For holding round objects, V-blocks are used along with jaws. Pipe vices with two serrated V-jaws are used by plumbers (Figs 7.5 and 7.6). Round jobs can easily

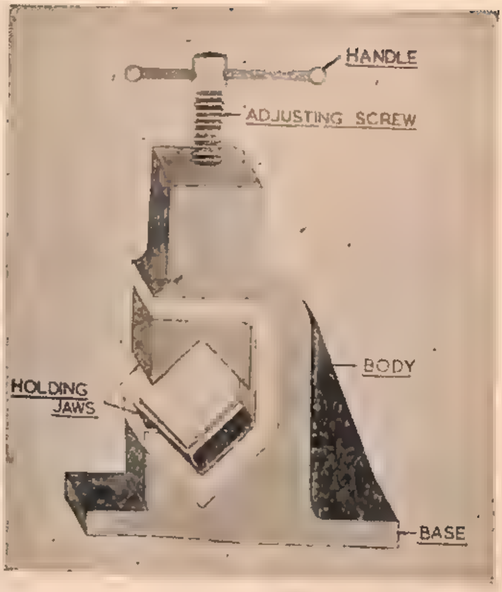


Fig. 7.6 Pipe vice

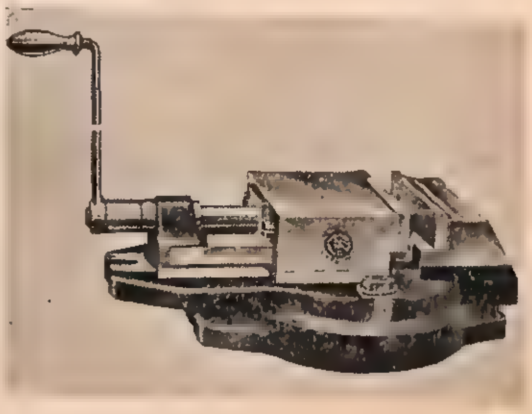


Fig. 7.7

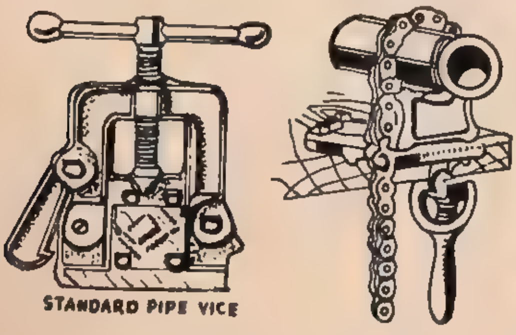


Fig. 7.5

be held in these vices. Chain pipe vices are also commonly used.

(b) *Machine vice:* This type is used with a machine tool and it is more accurate and more universal. Sometimes it is supplied with machined jaw without serration for holding finished components. Both plain and universal vices are used with machine tools. Universality is obtained by incorporating swiveling arrangement about one or more axes (Fig. 7.7). In precision vices tennons are provided to fit closely in the slots on the machine table. The actuation of the vice is done by a screw and nut arrangement. Sometimes hydraulic and pneumatic powers are used for actuation. In swivel vices angular markings are given to indicate the magnitude of rotation. Both bench vice and machine vice are specified by the width of jaws.

(c) *Hand vice :* This is a small gripping

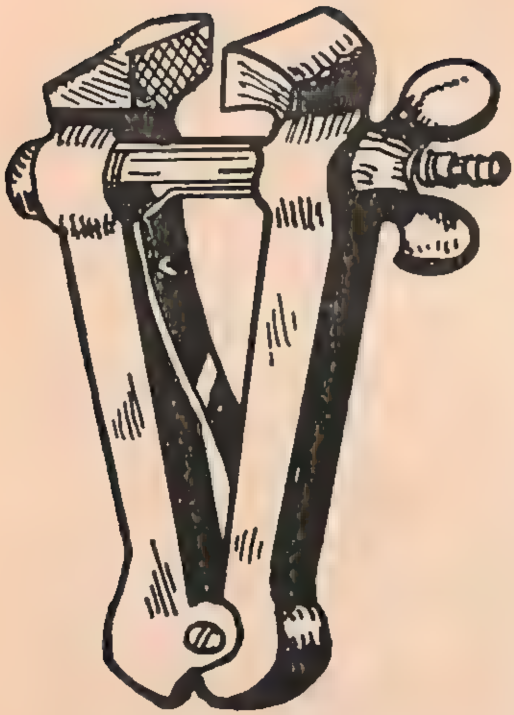


Fig. 7.8 · Hand vice

tool used by fitters to hold smaller objects in hand for filing or cutting operation (Fig. 7.8). It consists of two jaws at the ends of two arms joined at the opposite ends by hinges. The arms can rotate round the hinges and the vice is actuated by means of a screw and a fly nut. There is a spring inside so that when the nut is loosened, the jaws open to receive the object.

(d) *Pin vice:* This is used for holding small round pins in hand (Fig. 7.9). It works on the principle of collet chucks. The collet chuck has a tapering outside with three split prongs. This outside taper fits in Sleeve B. The Sleeve B fits the screw head of the prong C. As the nut A is tightened, it draws and closes the prong C when its own taper is pressed by the inside taper surface of the sleeve. Thus the pin D is tightly gripped. Opposite rotation of the nut A releases the pin.

(e) *C-Clamp:* It is so named because of the similarity of its shape with the letter C (Fig. 7.10). This also works on screw and nut principle. It is made to different sizes and is very useful. The section of the body which is forged, is made to resist higher loads for a certain cross-section of the material.

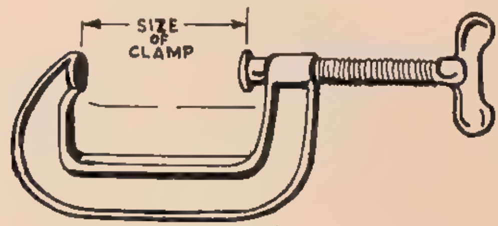


Fig. 7.10 C-clamp

(f) *Tool maker's clamp :* Also called the parallel clamp, this is very commonly used to hold a flat object against an angle plate for any operation. It is also used to grip small objects for drilling or some other operation. It consists of two hardened parallel steel pieces fitted with screws, as shown in Fig 7.11. The jaws move parallel to each other and are actuated by two screws.

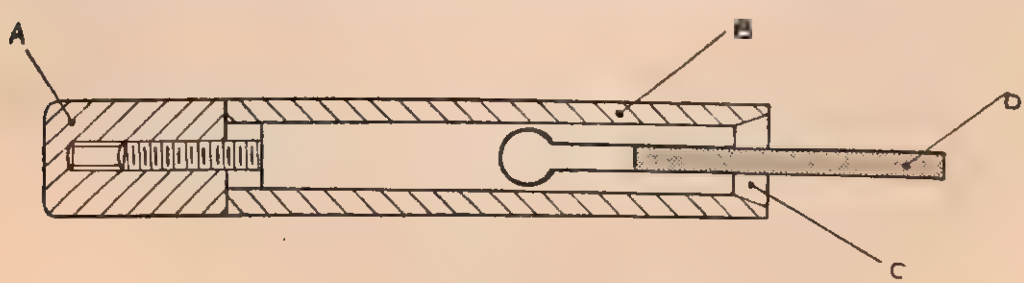


Fig. 7.9 Pin vice

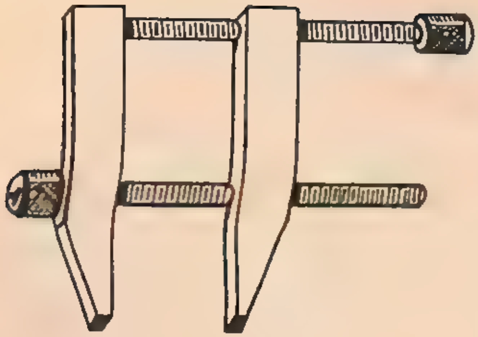


Fig. 7.11 Tool makers' clamp

STRIKING TOOLS

These tools are used for giving impact blows manually in operations like chiselling, flattening, etc. In designing such tools, the following points should be considered: (a) the magnitude of the blow, (b) the most easy and convenient way of handling the tool and converting human energy into impact blows, and (c) longer life of tools.

The magnitude of the blow depends on the weight of the hammer because the magnitude of the impact is the momentum or product of mass and velocity of the hammer. So, the mass and the velocity are to be adjusted to suit a job. The mass of the hammer cannot be very great as it is to be handled by men. The velocity, too, is limited by the physiology of human beings.

For maximum advantage, the hammer is designed to have a piece of iron weight at the head of the handle. The velocity can be increased by increasing the length of the handle but considerations of ease and convenience of use delimit this. So, a proper combination of hammer head and handle has to be made.

The handle is made of some springing wood, specially hickory, to absorb the shock of impact transmitted. The handle is sized and shaped at the end for good gripping and the throat is made to have a comparatively narrow elliptical section for spring action. After the handle is fitted to the hammer head, it is kept immersed in lubricating oil for 10 or 15 days to absorb oil. It is then shellacked and used. This treatment gives longer life to the handle and increases its shock absorbing capacity. The hammer head has a tapered hole at the centre called the eye of the hammer. The end of the handle is fixed in the eye and a metal wedge is inserted so that the handle does not slip (Fig 7.12). The shape of the hammer head is determined by the requirements of the operations which will be described later. For longer life and for its ability to withstand impact, the head is made of steel by the forging process and is hardened and tempered. The striking end of the hammer is chamfered and radiused (Fig. 7.12), so that it may not produce indentations on the surface which it is striking.

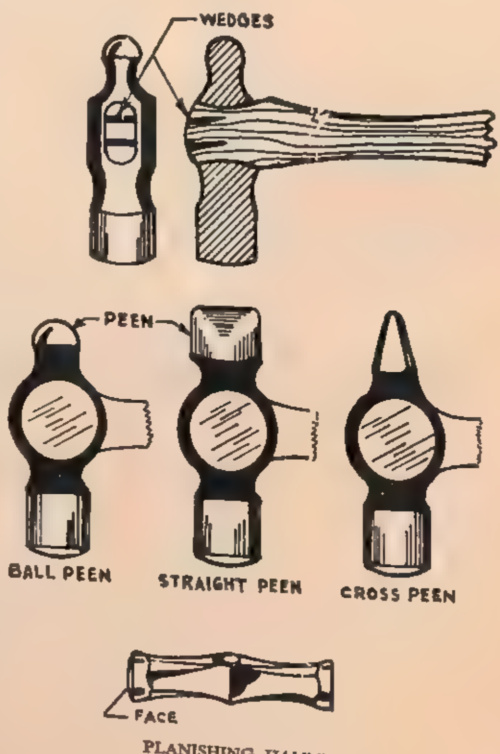


Fig. 7.12 Hammer heads

Ball Peen Hammer

This is a machinist's hammer as it is constantly used by a machine man, a fitter or an assembler. It has a round shaped peen at one end and a radiused face at the other. The peen end is convenient for the rivetting operation. A machinist's hammer weighs from 1 ounce to 3 pounds without the handle. For an ordinary work in the shop, hammers weighing 3/4 to $1\frac{1}{2}$ lbs are used. Heavy hammers with longer handles are used in iron smithy shops where higher impact blows are necessary to form the hot metal. These are called sledge hammers. Very light type hammers are used by gold and silver smiths or in watch making and other precision work. Fitters use hammers for chiselling, flattening, rivetting, centre punching, etc.

Straight and Crossed Peen Hammer

These hammers are shown in Fig. 7.12. These hammer heads are used for stretching metals or for making inside shoulders or bends. The peen heads of hammers are also used for hammer finishing.

Planishing Hammer

This hammer head is shown in Fig. 7.12. It has very good flat faces which are used for flattening and smoothening metal faces. This hammer hardens and strengthens the metal surface, besides finishing it.

Double-faced Hammer

This is used for striking cup tools for forming heads of rivets.

Soft Hammer

This hammer is made of hide or plastic and sometimes of wood. It is used for striking machined surfaces or soft metals. A soft hammer does not leave marks on the faces of the object. This tool is also called a mallet (Fig. 7.13).

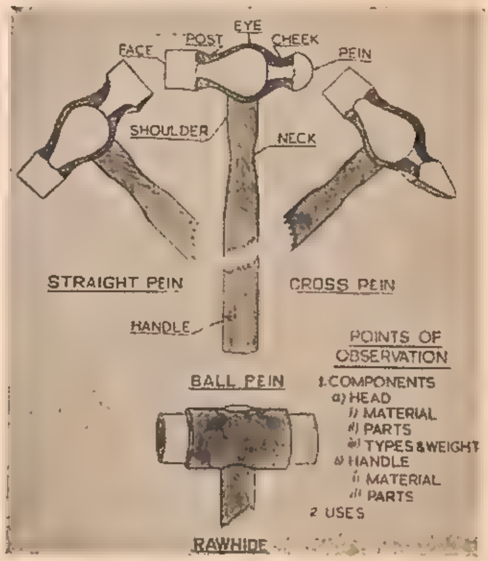


Fig. 7.13 Hammers

Hammering Operation

A hammer is gripped by the right hand at the end of the handle and not in the middle. In heavy work, it is brought down by swinging the arm from over the head. In light work, only the forearm is swung.

CUTTING TOOLS

A cutting operation consists in engaging a tool and an object properly and giving them a relative motion by means of power. The power may be given manually by pressure or impact or by some electrical or mechanical means.

As a rule, the cutting tool is harder than the material which it is to cut. A knife cuts a piece of wood, a snipe cuts a piece of sheet metal, a chisel cuts a piece of iron block, a file cuts a metal piece,

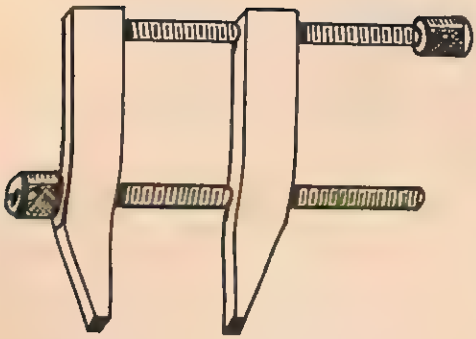


Fig. 7.11 Tool makers' clamp

STRIKING TOOLS

These tools are used for giving impact blows manually in operations like chiselling, flattening, etc. In designing such tools, the following points should be considered: (a) the magnitude of the blow, (b) the most easy and convenient way of handling the tool and converting human energy into impact blows, and (c) longer life of tools.

The magnitude of the blow depends on the weight of the hammer because the magnitude of the impact is the momentum or product of mass and velocity of the hammer. So, the mass and the velocity are to be adjusted to suit a job. The mass of the hammer cannot be very great as it is to be handled by men. The velocity, too, is limited by the physiology of human beings.

For maximum advantage, the hammer is designed to have a piece of iron weight at the head of the handle. The velocity can be increased by increasing the length of the handle but considerations of ease and convenience of use delimit this. So, a proper combination of hammer head and handle has to be made.

The handle is made of some springing wood, specially hickory, to absorb the shock of impact transmitted. The handle is sized and shaped at the end for good gripping and the throat is made to have a comparatively narrow elliptical section for spring action. After the handle is fitted to the hammer head, it is kept immersed in lubricating oil for 10 or 15 days to absorb oil. It is then shellacked and used. This treatment gives longer life to the handle and increases its shock absorbing capacity. The hammer head has a tapered hole at the centre called the eye of the hammer. The end of the handle is fixed in the eye and a metal wedge is inserted so that the handle does not slip (Fig 7.12). The shape of the hammer head is determined by the requirements of the operations which will be described later. For longer life and for its ability to withstand impact, the head is made of steel by the forging process and is hardened and tempered. The striking end of the hammer is chamfered and radiused (Fig. 7.12), so that it may not produce indentations on the surface which it is striking.

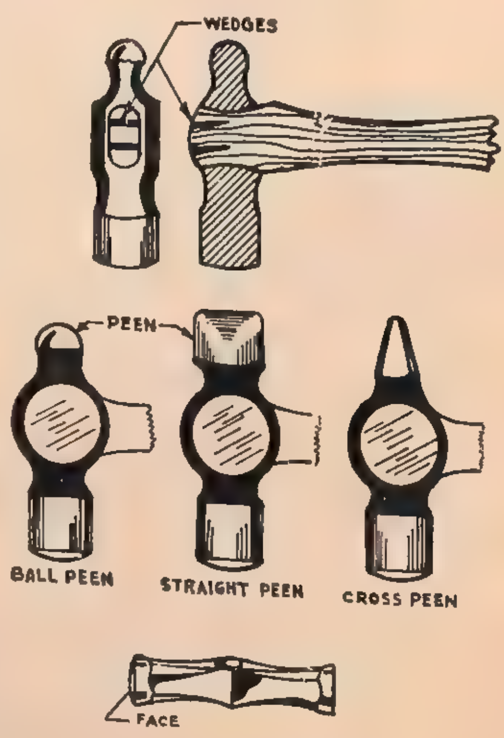


Fig. 7.12 Hammer heads

Ball Peen Hammer

This is a machinist's hammer as it is constantly used by a machine man, a fitter or an assembler. It has a round shaped peen at one end and a radiused face at the other. The peen end is convenient for the rivetting operation. A machinist's hammer weighs from 1 ounce to 3 pounds without the handle. For an ordinary work in the shop, hammers weighing 3/4 to $1\frac{1}{2}$ lbs are used. Heavy hammers with longer handles are used in iron smithy shops where higher impact blows are necessary to form the hot metal. These are called sledge hammers. Very light type hammers are used by gold and silver smiths or in watch making and other precision work. Fitters use hammers for chiselling, flattening, rivetting, centre punching, etc.

Straight and Crossed Peen Hammer

These hammers are shown in Fig. 7.12. These hammer heads are used for stretching metals or for making inside shoulders or bends. The peen heads of hammers are also used for hammer finishing.

Planishing Hammer

This hammer head is shown in Fig. 7.12. It has very good flat faces which are used for flattening and smoothening metal faces. This hammer hardens and strengthens the metal surface, besides finishing it.

Double-faced Hammer

This is used for striking cup tools for forming heads of rivets.

Soft Hammer

This hammer is made of hide or plastic and sometimes of wood. It is used for striking machined surfaces or soft metals. A soft hammer does not leave marks on the faces of the object. This tool is also called a mallet (Fig. 7.13).

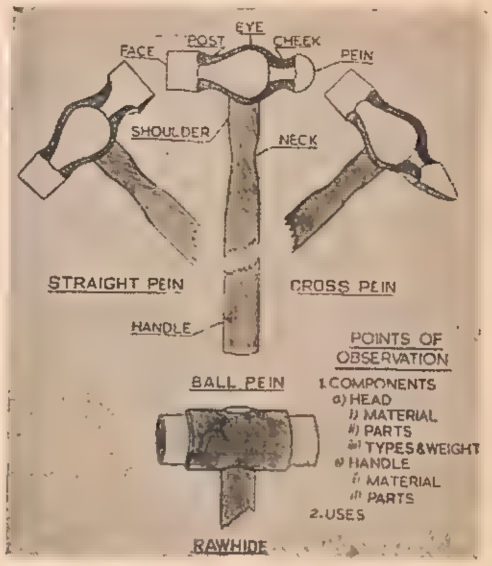


Fig. 7.13 Hammers

Hammering Operation

A hammer is gripped by the right hand at the end of the handle and not in the middle. In heavy work, it is brought down by swinging the arm from over the head. In light work, only the forearm is swung.

CUTTING TOOLS

A cutting operation consists in engaging a tool and an object properly and giving them a relative motion by means of power. The power may be given manually by pressure or impact or by some electrical or mechanical means.

As a rule, the cutting tool is harder than the material which it is to cut. A knife cuts a piece of wood, a snipe cuts a piece of sheet metal, a chisel cuts a piece of iron block, a file cuts a metal piece,

diamond cuts glass, a grinding wheel cuts hardened steel and so on. But besides being hard, a cutting tool has other characteristics for efficiency and longer life. It must
(1) be strong to withstand cutting pressure,
(2) have keen edge for clean and efficient cutting,
(3) have wear-resisting properties (being hard) for longer life, and
(4) be economical.

Among the materials found suitable for cutting tools are high carbon steel and alloy steel, including high speed steel. These are machineable when soft but can be hardened with proper heat treatment. In fitting work, the cutting tools are mostly made of high carbon steel and sometimes of high speed steel. The cutting tools are generally hardened and tempered only at the cutting edge end, the rest remaining tough. Hardness increases brittleness and makes the tool edge liable to chip off under shock load.

CLASSIFICATION OF CUTTING TOOLS

The cutting tools for fitting shop work can be classified, as below, according to the nature of metal removal.
(a) Chisels for chipping material or for cutting.
(b) Saws for parting off sections.
(c) Shears for cutting off sheets of metal.
(d) Files for removing smaller amount of metal by the pressure of hand and for producing smooth surfaces.
(e) Drills for opening a hole in a metal block or enlarging a hole.
(f) Scraping to remove very small amount of metal from a surface for better finish.
(g) Threading tool to cut thread, both internal and external.

Important points to be observed in the use of all these tools are the design of the cutting edges, the way of removing the material and the efficient way of using them.

CHISELS

Various types of chisels are shown in Fig. 7.14. Chisels in the fitting shop are

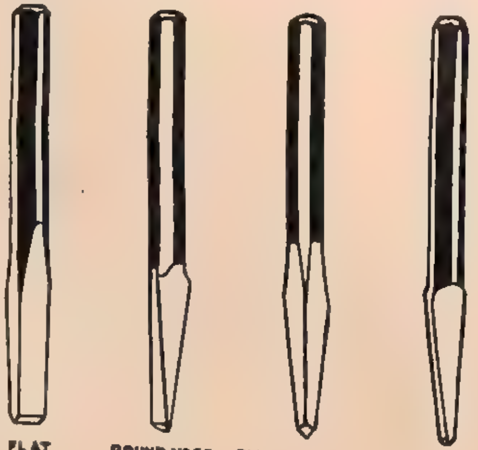


Fig 7.14

used on cold metal and are sometimes called cold chisels. In smithy, chisels are used on hot metal. The size of a chisel is determined by the type of work to be done. In goldsmithy or any other ornamental and fine work, small light chisels having various cutting edges are used. For normal work, medium type chisels of 1/2″ to 1″ diameter, of octagonal sections and 6″ to 8″ long with different cutting edges, are used.

Chisels are named according to the cutting edge or the type of work or groove they are to produce. There are flat chisels, cross-cut chisels, diamond-point chisels, round nose chisels, etc. (Fig. 7.14). The angle of the cutting edge of a chisel varies from 50° to 75°. For softer material, the angle is less than that for harder material. The edge is hardened by tempering, but the body is kept tough. If it is not

tempered, the body or the head, being brittle, may break under the striking of a hammer. The head of a chisel is chamfered as shown in the figure. After some use, the head gets a mushroom-like form owing to the flow of material under constant striking. This should be removed, otherwise small parts from this ragged head may fly off under the impact of hitting and may cause injury.

A chisel is generally made from octagonal rods to facilitate better gripping. Round chisels are also occasionally used. Chisels are made by the forging process, then ground for the cutting edge and finally hardened and tempered.

Operation of a Chisel (Chipping)

A right-handed man holds the chisel in the middle with his left hand and hammers with his right hand. The chisel is held against the object at the cutting point and the hammer is hit on the head of the chisel. At this time, the eyes of the operator should be fixed at the cutting point and not at the head. Chisels should not be gripped very tight, for then the shock of hitting will be felt by the operator. A learner may hit his left hand in the beginning but gradually he gets habituated to hitting the chisel head correctly. This practice is for a heavy job; for a light job, the chisel is held by fingers.

While chiselling, one must always use a pair of goggles. A suitable guard should be put so that chips or particles flying from the job may not injure others (Fig. 7.15).

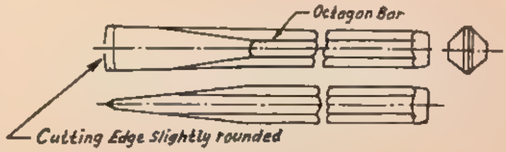


Fig. 7.16 Flat chisel

Flat Chisel

This chisel has a wide cutting edge (Fig. 7.16). The corner point is rounded off to ensure longer life. It is used for chipping flat surfaces and cutting steel or metal rods (Fig. 7.17). The size of a flat chisel is 1/2″ to 1″ for a medium and heavy job.

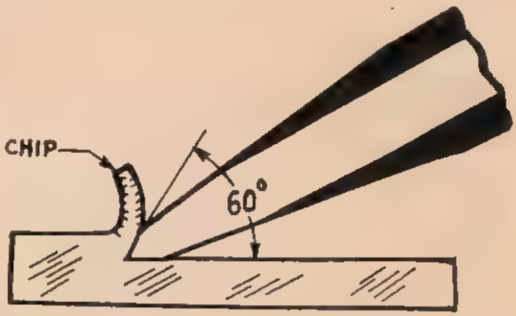


Fig. 7.17 Cutting action of chisel

Cross-Cut Chisel

This has a narrow cutting edge and is used for cutting keyways and grooves. The cutting edge size varies from 1/8″ to 1/2″. The edge is a little wider than the back for the sake of clearance (Fig. 7.14).

Fig. 7.15 Chipping

Diamond-Point Chisel

This tool is so named because the cutting edge looks like a diamond-point. It is used for cutting oil grooves and squares in a corner (Fig. 7.14).

Round-Nose Chisel

This has a half-round cutting edge and is used for cutting round corners and grooves (Fig. 7.14).

FILE

This tool is indispensable to a fitter. It is used to remove small amount of material from a metal surface and to give it a smooth finish and close dimensions. It is made of high grade steel by drop stamping process. It is flat with slanting rows of teeth on its surface (Fig. 7.18). It is these hardened teeth that cut the material.

to make the tool convenient for different types of jobs.

A file is specified by its length, cross-section, shape, cut and spacing between the rows of teeth. The length of a file is considered to be the length from its heel to the end point. The common sizes are 6″, 8″, 10″, 12″, but files of other sizes are also available.

Files are manufactured to hundreds of shapes and cross-sections. Tapered files are gradually thinner and narrower from the heel to the point, whereas a file has uniform width and thickness throughout. The commonly used files named after their cross-sections, are shown in Fig. 7.19. Each type has its specific use.

Files have generally three types of cut: (a) single cut, (b) double cut and (c) rasp cut. A single cut file has rows of teeth across the face of the file parallel to one direction and making an angle of about 60° with the centre line of the file. Every

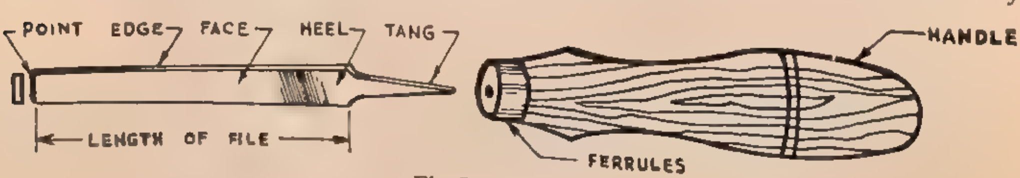


Fig. 7.18 Flat file

A file consists mainly of three parts: (a) tang, (b) heel and (c) body. The tang or the pointed part is fitted inside a wooden handle, the end of which is strengthened by a metal ferrule, so that the handle does not split (Fig. 7.18). The heel is in between the tang and the body and has no teeth, but carries the manufacturer's name and trade mark. The main body is the operating part. It has generally two faces and two edges, all may have cutting teeth. When the edges do not have cutting teeth, they are called safe edges. The dimension of the handle must give it a good grip. The length and the cross-section of a file are designed

tooth looks like the edge of a chisel. A double cut file has rows of teeth in opposite directions crossing each other so that they make angles of about 60° and 80° with the centre line. The cutting teeth look like sharp points. The rasp file has raised-point teeth far apart and is used only on wood and leather. The double cut files remove metal faster than the single cut files but make the surface comparatively rough.

These two types of files are further classified according to the spacing between the rows of teeth. More spacing makes the file produce rougher surface and less spacing smoother surface. Files may be

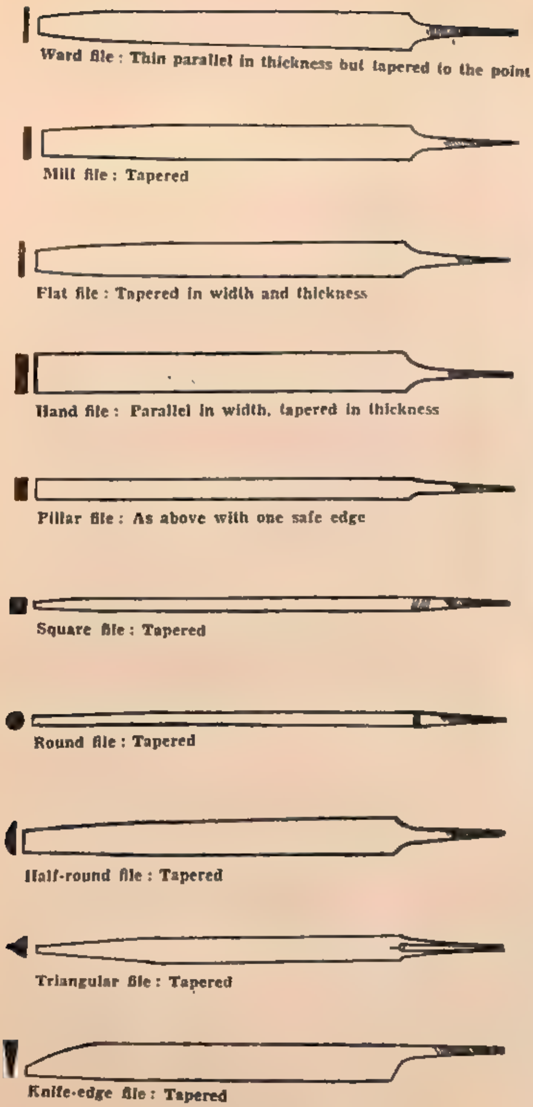


Fig. 7.19 Type of files

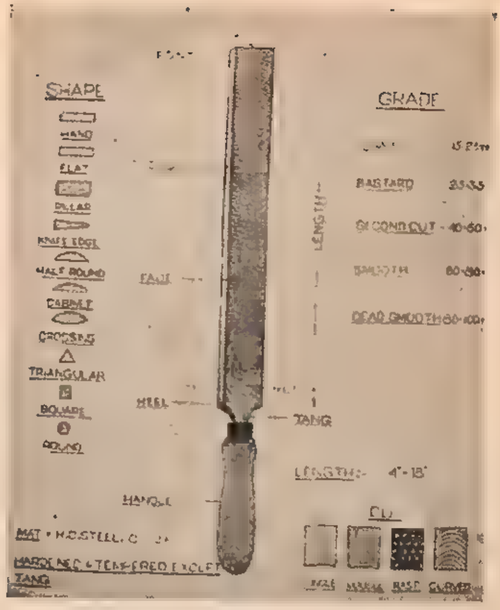


Fig. 7.20 File

(a) rough, (b) coarse, (c) bastard, (d) second cut, (e) smooth, (f) dead smooth (Fig. 7.20). The larger the file the coarser it is. Dead smooth files are known as swiss files and are used in precision work. An example of how to specify a file is: 10″ flat double cut coarse file.

The grades of files are selected according to the desired rate of metal removal. The table below gives an approximate idea of this.

TABLE

Operation	*Grade of selection*	*Approximate pitch of teeth*
For filing castings and for heavy metal removal	Rough	20 TPI
For heavy filing	Coarse	25 TPI
For moderately heavy filing	Bastard	30 TPI
For general work	Second cut	40 TPI
For fine filing to close dimensions	Smooth	50-60 TPI
For small precision work	Dead smooth	100-120 TPI

OPERATION WITH A FILE

Filing is an art and this can be mastered by practice and with patience. To a learner filing seems to be the easiest job, but an expert fitter knows that it requires a long experience to master the trade. A die maker is the master of the art of filing and his is the most skilful and highly paid job. The worth of a fitter is judged by his skill in the use of files.

The operation of filing consists of holding the object in a bench vice at the *correct height, selecting the proper file,* standing in the proper position, holding the file correctly, and using the file with *proper pressure (Fig. 7.21 & 7.22).*

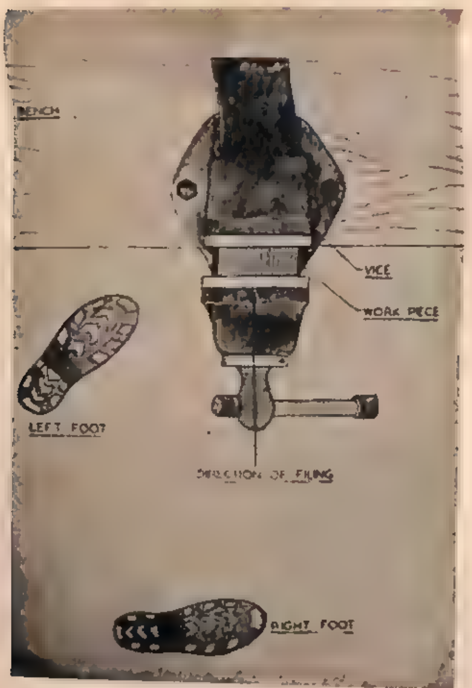


Fig. 7.21 Position of feet in filing

Fig. 7.22 Filing

Holding

The object to be filed is held just below the level of the operator's elbow. To avoid chattering sound, the surface to be filed must be placed as near the gripping jaws as possible. To avoid marks of jaws on the object, soft jaw caps should be used. For a light and precision job, the fitter generally sits on a stool and files so that the object is nearer to his eyes. In this case, only fingers are used to hold the smaller file and the fore-finger guides the motion.

Postures for Filing

For a right-handed worker, the left leg should be forward and the right leg behind,

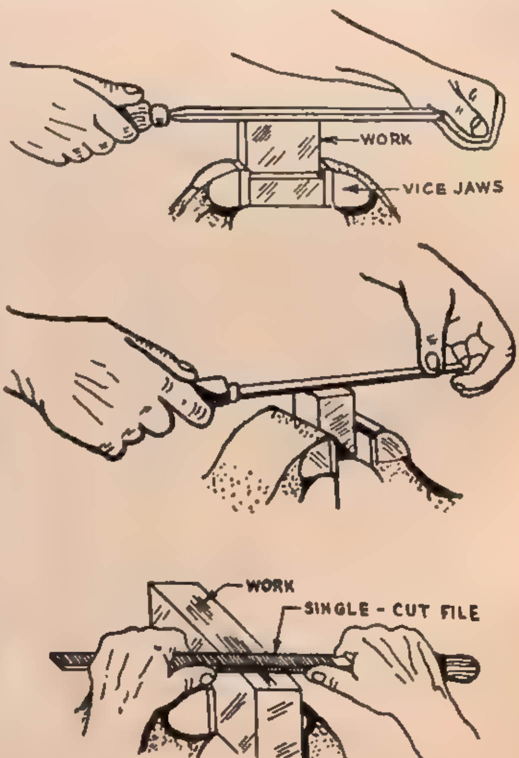


Fig. 7.23 Some filing methods

the gap between the steps being 10″ to 12″. The body thus remains a bit inclined and swings forward and backward on the feet *alongwith the forward and backward strokes of the file. The arms move only* slightly (Fig. 7.23).

Pressure and Cutting Speed of Filing

The file handle is gripped with the right hand by a right-handed worker and the left hand puts pressure near the tip of the file. The right hand also applies pressure along with the pushing of the file during the forward stroke. Since the file cuts only on the forward stroke, pressure is required only in that stroke. The backward stroke being idle, the file is drawn in without pressure from either hand. As the file is moved steadily under pressure from both hands, some balance of pressure has to be maintained during the cutting stroke so that the cut surface remains flat, otherwise it becomes convex as generally happens in the operation by a learner. An old file requires more pressure than a new one as the former has less sharper cutting edges than the latter.

Regarding the cutting speed of filing, the filing speed should be steady and slow, but the pressure should be high so that more metal can be removed at every stroke. The harder the material, the slower will be the speed.

SOME FILING METHODS

Cross filing is filing first at an angle of 45°, with the job in one direction for sometime, then filing at the same angle in a direction at right angles to the earlier direction. In this way, flat surface can easily be produced by filing.

Draw filing is a method in which a file is held by both hands at 3/4″ from the work-edges and is drawn back and forth along the edges, as shown in Fig. 7.23. The pressure is applied only in the forward stroke. *Flat surfaces are given a finish in this way.*

Testing the Filed Surface

The surface when filed is tested for flatness and squareness with other related surfaces. The flatness is checked by a straight edge or the edge of the blade of a try-square against light. If it is tolerably flat, uniform light is seen all through the gap. The squareness is tested by setting a try-square or an angle protractor with the base on the datum surface and the blade on the filed surface. Then the surface and the blade are checked against light.

Filing Hard and Soft Metals

A file can only cut material softer than itself. A hardened object should never be filed, for that will spoil the file. Sometimes an operator uses the corner of a file to test whether a piece has been hardened or not. A file should not be used on the scaled and chilled surfaces of cast iron. In this case, first a chisel should be used to remove the hardened layer and then the surface filed.

For soft metals, coarse files are used. If second cut or smooth files are used, the teeth get clogged with chips of softer material in a few strokes and then they do not cut.

Care and Maintenance of Files

Files are hardened tools and hence they should not be kept together in contact with one another. They should be kept separated in wooden ways or should be hung separately. A file should never be used for hitting as it is brittle. Care must be taken

to keep the file away from contact with grease or oil. If a file is thus spoiled, the surface may be rubbed with chalk and cleaned with a file brush. Every time, after use, the file teeth ought to be cleaned with a file brush made of steel wire.

SCRAPERS

These tools are used for scraping metal surfaces. The scraping operation consists in removing manually very thin slices of metal from a surface by means of a keen-edged tool. The high spots of a machined surface are removed to give it a better bearing with the mating surface. The fitting of soft bearings to shaft is often done by the scraping process after machining. Flat surfaces like surface plates or machine tool guides are also finished by scraping for better bearing.

Scrapers are of many shapes which depend on the nature of work to be done. Flat, triangular and half round scrapers are mostly used (Fig. 7.24). The first one is used on flat surfaces and the last two on curved surfaces. Like all other tools, the scraper is hardened and has keen cutting edges. There is a handle at the end for gripping. Old files can be ground and sharpened at the tips to form scrapers.

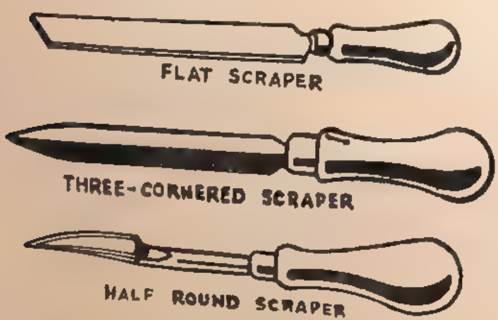


Fig. 7.24

Operation

Like filing, scraping also requires great skill on the part of an operator.

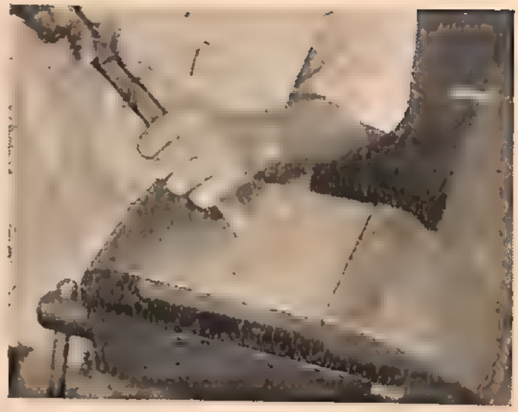


Fig. 7.25

Pressure, holding position and movement of hand for shaving material are the most important aspects of the scraping process. Fig. 7.25 shows how to scrape a flat surface.

It is important to locate and mark the high spots before scraping the surface, equal to or larger than the mating surface used for it. A light thin film of prussian blue or red lead is rubbed over the surface to be scraped. Then it is laid on the master or mating part and is slide to and fro. High spots on the surface will lose colour and shine. Now, with the help of a scraper the high spots are removed. The operation is repeated till the mating of the two surfaces is attained to the desired degree. In the absence of a master plate, surface plates can be produced three at a time, by mating one with another in order and then correcting them by scraping. The perfect mating between themselves will only be possible when all of them become flat.

SHEARS

These are scissors-like tools to cut sheet metal. They are also called snips. For light gauges, hand snips are used, but for heavy gauges or for faster work, powered snips, which are available in portable sizes, should

be used. These are normally electrically or pneumatically powered. Like other cutting tools they are hardened and have keen cutting edges, but they work in pairs. The tool is gripped by hand and the two arms are pressed. It works on the principle of the first kind of lever. Mechanical advantage is accomplished by extending the gripping arms, but this extension is limited by human capacity.

The snips are classified according to the shape of their cutting edges. They may be (i) straight, (ii) curved or (iii) bent (Fig. 7.26). The first type is used for straight

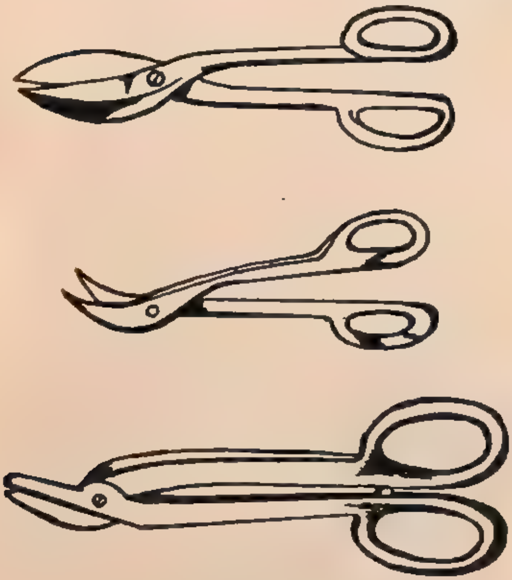


Fig. 7.26 Types of snips

cutting. The second one is used for external and internal contour, and the third is used for trimming purposes. Shears are extremely useful in tin smithy.

SAWS

These cutting tools are thin blades with rows of teeth at one edge (Fig. 7.27). The teeth are sharp and have rake and clearance angles. As the teeth and the tool body are

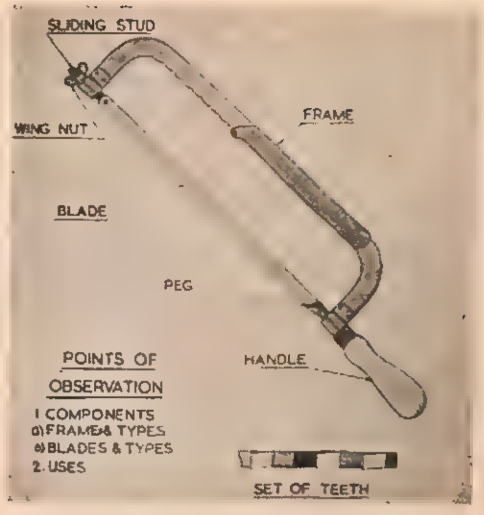


Fig. 7.27 Hack saws

both required to go deep into the object for cutting it off, the teeth are projected (bent) side ways to cut a wider groove and provide clearance for the blade to pass through. Wood working saws, which have been described earlier, are similarly designed. The blade is thin and is held in a steel frame (Fig. 7.28). The manual metal working saw is commonly known as the

Fig. 7.28 Sawing

hand hacksaw. It consists of a frame, a handle, prongs and the screw-nut arrangement for tightening the blade. The frame may be solid or adjustable so as to accommodate saw blades of different lengths. The blades have two holes at the two ends to fit the prongs.

The saw blades are made of high grade steel. They are heat-treated, i.e., hardened and tempered. Sometimes only the teeth are hardened and the back remains soft. These are less liable to break.

Specification

Saw blades are specified by the length and pitch of their teeth. The length of a blade is measured as the distance between the centres of the holes at the ends and the pitch of the teeth is the number of teeth per inch. The sizes available of the saws for hand sawing operation are 8″, 10″ and 12″. For common type of metal working, saws with 18 to 24 t.p.i. are used. The thinner the desired section, the finer should be the pitch to be used.

Operation with a Hand Hacksaw

An operator first chooses a suitable blade and then fixes it in the frame in such a way that the forward stroke becomes the cutting stroke (Fig. 7.28). The wing nut at the end of the frame should be tightened properly and the blade should not be kept loose. The object to be cut is suitably fixed on a fitter's bench vice. The work should be fixed a little below the elbow of the operator. The cutting zone should be near the gripping jaws, otherwise there would be chattering sound during sawing. The position of the body is as important in sawing as in filing. Pressure should be applied by both hands on the forward stroke. The normal speed of cutting is about 40 strokes per minute. No pressure is required on the backward stroke. A new saw cuts more easily and with less pressure than a worn-out saw.

To saw an object, a notch is first made at the required point by the backward stroke of the saw with a finger as guide. Sometimes a file is used for this notching. Then slowly the material is cut with the forward strokes. The first few strokes should be made continuously.

If a badly worn-out blade is used, no clearance is obtained for the blade and the blade rubs on the sides causing excessive heat and without much progress in cutting. In such a case if the blade is changed, the new blade should not be used in the cut of the worn-out blade because the width of the slot cut with the old blade is smaller and the new blade will not proceed in the narrower slot made by the worn-out blade and will probably break. A fresh cut should be started with the new blade. A blade is also liable to break easily when a thin metal is cut. It produces chattering sound. For smooth cutting of thin metals, wood pieces are used as backing material and then sawing is done.

Fig. 7.29 Power hacksaw

Power Hacksaw

This is a machine tool for sawing material (Fig. 7.29). The hacksaw blade is

held in a frame and the whole frame is made to move to and fro. Here the saw cuts in the backward stroke and the blade is fixed accordingly. The object is held with a vice in the horizontal position. Cutting pressure is obtained by the weight of the frame or by a dead weight fixed along a slide rod on the frame. The weight of the frame is counter-balanced by a hydraulic piston. This is arranged in such a way that the hydraulic pressure lifts the frame in the forward stroke to give it relief. But in the backward stroke, as the hydraulic pressure is less than the weight of the frame, the cutting pressure is given. As the cutting progresses, the frame comes down and the cutting pressure is exerted all along. This machine tool is electrically operated.

Band Saw

Like the power hacksaw, band saw machines (Fig. 7.30) are also electrically operated. These may be portable or big machine tools.

Fig. 7.30 Band saw

The band saw uses endless steel tape like the saw with the cutting teeth at one end. This tape is called the band saw blade. This is a faster method of cutting because there is no idle stroke; the band moves only in one direction and cuts continuously.

7.7. Threads and Threading Tools

Thread is a helical wedge-like ridge around the outside or inside cylindrical surface. This thread is generally used for fixing. A round bar with thread on it is known as a bolt or screw and a round hole with thread inside is known as a nut. A screw and a nut of the same size form a pair. The threads of a pair of screw and nut should conform to or fit each other so that fixing is properly done. Sometimes threads are found on conical surfaces (wood screws) and flat surfaces called scroll.

The introduction of screw has revolutionized the technological world. This is the most important means of mechanical assembling. The main purpose of a screw and a nut is fixing and this screw (helical ridge) should be designed to transmit power effectively. This is why in this case the form of a thread is V-type or it must have more metal at the base of the form (buttress thread). For guiding purposes also, screw and nut are used. In this case the preciseness of the form and the pitch is extremely necessary.

A screw may have a left-hand or a right-hand thread. A right-hand screw gets into a nut by clockwise rotation and a left-hand screw by anti-clockwise rotation. The threads commonly used in engineering are right-hand threads.

SPECIFICATION OF THREADS

A thread is specified by the following data: (a) outside diameter, (b) root diameter, (c) pitch diameter, (d) form of thread, (e) pitch of thread.

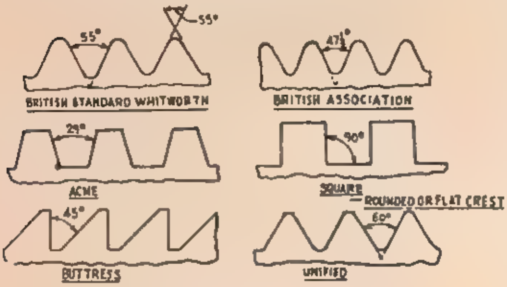


Fig. 7.31 Types of threads

Fig. 7.32 illustrates the point. For a bolt, the diameter of the cylindrical surface on which a thread is cut is called the outside or major diameter. The diameter up to which the groove is to reach for the formation of a thread is known as the root diameter. The radial depth of the groove for forming thread is called the depth of a thread and is equal to half the difference between the outside and the root diameter of a thread.

Pitch is the distance from the centre of one thread to the centre of the next one. Pitch lines are those imaginary lines cutting across the threads along which (i.e., the lines) the thread width is equal to the gap width. There may be an infinite number of pitch lines which together may form an imaginary cylinder. The diameter of a section of this cylinder is called the pitch diameter, which is, in fact, the distance between the two diametrically opposite pitch lines. This is equal to the difference between the outside diameter and the depth of a thread.

In the inch system, it is convenient to express pitch by the number of threads per inch, i.e., in t.p.i. Screw threads may have single-start, double-start or multi-start threads. This means that one, two or more continuous grooves can make a screw thread. For a single-start thread, if the screw is rotated 360°, the nut will move axially by the distance of the pitch. In the case of a double-start thread, for one complete rotation of the screw, the nut will proceed axially two times the pitch and so on. The axial movements of the nut for one rotation of the screw or vice versa is called lead. So, for an n-start thread lead=nx pitch. The advantage of the multi-start thread is the engagement of a number of threads in one rotation. The thread of a cap of a fountain pen may be observed as a case in point.

Forms of threads vary to a great extent from country to country. Each country has its own standards of thread. Even different industries sometimes have their own standards, as, for exàmple, electrical threads, cycle threads, pipe threads, etc. But there are certain international standards which obtain in all trades and climes. In India we are now in a period of transition from the inch standard to the metric standard. The metric standard is an international standard. Some types of threads are shown in Fig. 7.31.

The form of a thread is specified by the angle between the two sides (mostly symmetrical except in the buttress thread), the curvature of the tip and the root of the thread. A standard specification always gives us all the details (Fig. 7.32). Threads are used in various works and they are often

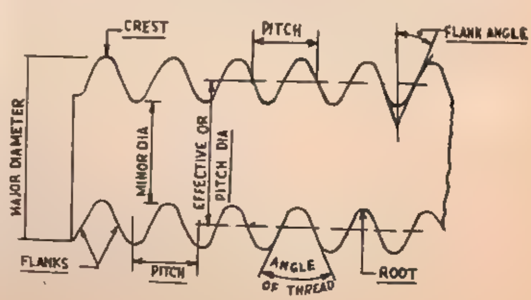


Fig. 7.32 Elements of a thread

required to have accurate dimensions to be of different grades. This is the reason why standards have been set for the classes of fit in a pair of screw and nut. For an ordinary work that is not so precise in nature, threads of wide tolerance in respect of form, pitch and dimension are used. The manufacturing cost of these threads is small. On the other hand, for close-fit work, precision threads are manufactured with very close tolerance. These threads are expensive.

TOOLS FOR THREADING

The methods of manufacturing threads vary according to the rate and quantity of production. But there are only two principles on which threads are cut. The ridges may be produced either by the cutting of grooves and removal of material, or by being raised from the base material by cold working. Both the methods are widely used in industry. In this book, only the groove cutting method will be discussed.

For machining grooves, either single-edged or multi-edged tools may be used. The single-edged thread cutting tools are used in lathe which will be discussed later. Multi-edged tools are used in bench work. These tools are also extensively used for mass production by machine tools.

All tools must have cutting edges of accurate form so that they can cut grooves to produce correct thread dimensions and forms. For multi-edged tools, the pitch is also a very important factor. These tools are generally made of carbon tool steel or high speed steel and are heat-treated.

Taps and dies are thread cutting tools used in shops. Taps are used for cutting internal threads and dies for external threads (Fig. 7.33). These tools form pairs, and are available in sets.

Fig. 7.33 Taps and die sets

TAPS

A tap is a screw-like tool with three or four grooves made axially to form a series of cutting edges. The grooves are so made as to give proper angle for efficient cutting. The cutting action of a tap form curly chips. Tapping may be done manually or by a tapping machine which is used for mass production. Fitters tap manually. Hand taps are generally three in one set (Fig. 7.33). They are : the first or taper tap, the second or plug tap and the third or bottoming tap. About five or six threads of the first tap are ground tapers for an easy starting of thread making. So, in the case of second tap three or four threads are ground. The bottoming tap remains intact and is used for cutting thread up to the end of a blind hole. A fitter must be very careful in using the taps otherwise they may break. The shank of a tap has a smaller diameter than the root diameter of the thread, for the tool has to clear through the hole it is tapping. But for a very fine

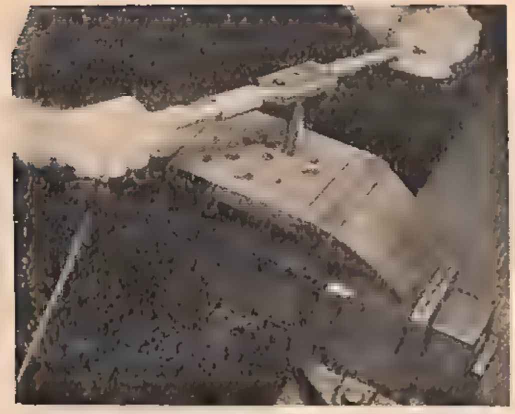


Fig. 7.34 Tapping by tap wrench

tap the shank diameter is not made smaller than the root diameter for making the tool strong. The shank has a square end for using a tap wrench (Fig. 7.34). This tap wrench has sliding 'V's to fit the heads of different sizes of taps. The torque for tapping is given by rotating the wrench handle.

Tapping operation

To machine a tapped hole, one should first find the size of the tap and the hole to be made first. The diameter of the hole should be equal to the outside diameter of the tap size less twice the depth of the thread. A full form thread will be formed in this case. This diameter of the hole is known as tap drill size. For manufacturing on a commercial scale, a tapping drill is made a bit bigger in size than the calculated diameter. This will produce 80 per cent of the thread form. Charts for tapping drill sizes should always be consulted before making a thread.

After the tap drill is made at a proper position, the piece is firmly held in a vice. A taper tap should be taken from the set and put inside the hole. A suitable tap wrench should be fitted to the tap end. Then the tap is placed square and pressed down. The squareness is checked by means of a try-square at two right angle positions. The tap is rotated by the wrench with a steady downward pressure. Once the tool starts forming thread, the squareness is checked again. If it is not correct, the taper tap is backed out of the hole and tried again with a little side pressure. This is repeated till the squareness is correct.

Once the tap is set, it is turned under pressure till the thread has had a good start. After that no downward pressure is necessary, only torque will do. Now rotated by means of the wrench, the tap goes down and the groove is cut. Tapping requires skill. After being turned and fed through a few degrees, the tap should be unturned, so as to break and clear away the cut chips. Thus tapping is done with a to and fro rotation all along. Once the taper tap appears to be tight, it is changed and the plug tap is used for some turns. Again, when the plug feels hard, the bottoming tap is used. And when the bottoming tap, too, feels hard to turn, the taper tap is used once again.

Thus successive changing of these three taps should be made till the tapping of the hole is complete. One should be very careful during these operations and get acquainted with the feel of pressure in tapping different sizes, otherwise the tap will break. The broken tap is a nuisance and cannot be easily taken out of the hole. For tapping steel, lard oil or white lead mixed with oil should be used as lubricant but cast iron may be tapped without any lubricant.

The drill press may also be conveniently used for correct tapping.

Precautions of tapping

The precautions to be taken in tapping are : (a) The tapping hole size should be correct. If it is small, the operation will

require great pressure which may cause breakage. (b) The correct feeling of tapping torque is necessary. (c) Constant feeding in and backing out are essential. (d) Use of lubricant is necessary. (e) Great care should be taken while tapping a blind hole.

THREADING DIES

These are the tools for making outside threads on round bars, i.e., threading on a bolt. These are either round or square pieces of heat-treated steel with a threaded hole. There are also small round holes which act as flutes to form cutting edges. Dies are not used in sets as taps. A single die has adjustment to form full threads. This tool may be of one or two piece threading dies. The former is called a button die or a round adjustable split-die. A little adjustment can be made by means of a screw by opening the split or by another screw closing the split. For holding and turning, the die and die holders (Fig. 7.33) are used. These are also called die stocks.

Like the tap, the die is also tapered for the convenience of starting a thread. The rod to be threaded is also bevelled for easier starting of threading.

THREADING SCREWS

The die is properly set in a die stock. The piece to be threaded should be measured. The dimension must be equal to the outside diameter of the thread size. For commercial screws the outside diameter should be calculated to form 80% of the thread. The bar is held rigidly in a vice or by any other gripping device. The die is set with the bevelled edge on the top. For correct guide and setting, a collet ring is sometimes used. Like a tap, a die is started with a twist and a steady pressure is maintained. The method of operation is the same in tapping, feeding in a few degrees and turning back for clearance of chips.

Lubricants are used as in tapping. A die is less susceptible to breakage than a tap.

7.8 Assembly Tools

Objective : These tools are mostly used in the dismantling and assembly jobs. The type of tool varies according to the type of job to be assembled. But there are certain common types used universally. These are screw drivers, pliers, hammers, clamps, wrenches. Some of them have been discussed earlier. Screw drivers, pliers, wrenches and punches are discussed here.

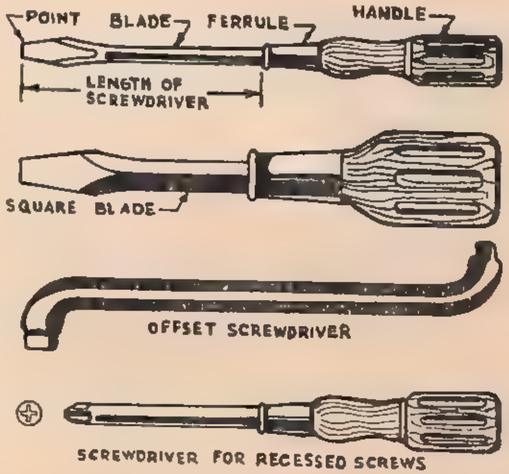


Fig. 7.35 Screw drivers

SCREW DRIVERS

A screw driver is used for turning a screw with slotted head. It is made of a steel blade with a flattened edge at one end and a wooden handle at the other. The point is shaped to fit easily into the slot of the screw which is to be turned. Generally, the blade is of a round section but

square or rectangular sections are used in heavy screw drivers. Different types of screw drivers are shown in Fig. 7.35. The head of a driver for coach screw (Fig. 7.35) is so designed that it fits the recess of the screw head. For certain types of assembly, offset screw drivers are also used.

The heads are made to different standard sizes to suit various types of screws. The sizes of these tools are expressed in terms of the length of the blade projected over the ferule of the handle. The blade is made of tool steel and the top is hardened and tempered.

ALLEN KEYS

There are other types of screw tightening drivers. They are bent and of hexagonal section to fit the socketed head screws. They are hardened and tempered all over and are manufactured in sets to fit different sizes of socketed head screws.

WRENCHES

These tools are also used for opening and tightening bolts and nuts of either square or haxagonal shapes. Generally, wrenches are used for heavier screws which have hexagonal or square heads. The wrenches can be broadly classified as (a) adjustable and (b) non-adjustable wrenches.

Adjustable Wrenches

These wrenches are shown in Fig. 7.36. In monkey wrenches, the jaws are adjusted by the nut and screw method. Adjustable end-wrenches have the movement of jaws guided by worm and rack arrangements. These wrenches are stronger than the monkey wrenches and are more handy to use. In addition to these, there are pipe wrenches which are used generally in the pipe fitting work.These adjustable end-wrenches are usually forged from aluminium alloys. The size of these wrenches is expressed in terms of their length.

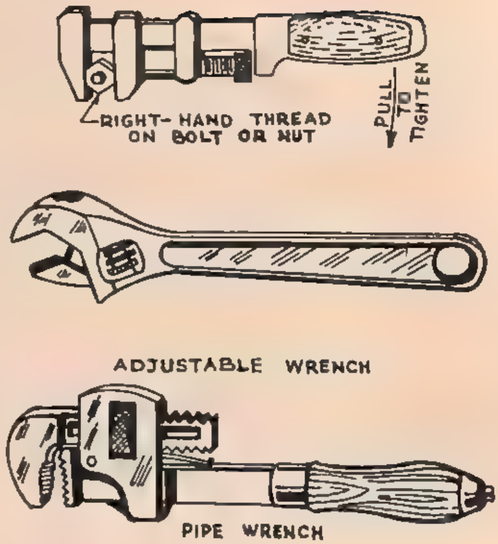


Fig. 7.36 Wrenches

Non-adjustable Wrenches

These wrenches (Fig. 7.37) may be either single-ended or double-ended, straight or s-shaped. They are also forged steel pieces and are available in different sizes to fit the heads of standard bolts. The size of a wrench is determined by the size of its opening and is stamped on the face.

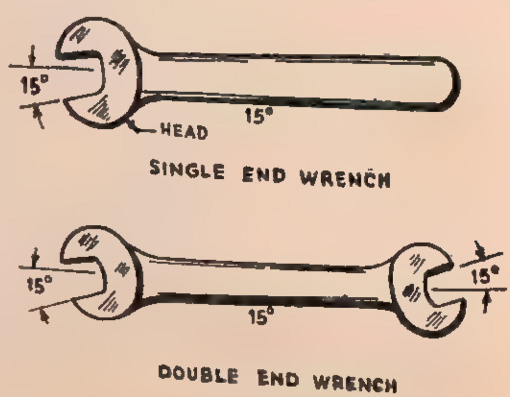


Fig. 7.37

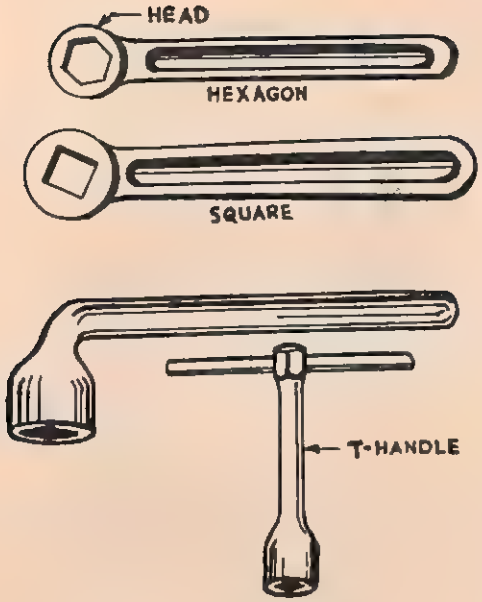


Fig. 7.38 Socket wrenches

In certain types of assembly, box wrenches and socket wrenches (Fig. 7.38) are used more conveniently than the others. If an adjustable wrench without proper adjustment or a worn-out non-adjustable wrench is used, the bolt head is liable to be damaged, resulting in the formation of round corners and slipping of the tool while tightening. But the use of a proper box wrench saves the head of the bolt. Socket wrenches are used for bolt heads or nuts in deep places or in counter-holes.

Then there are spanners such as C-spanner, pin spanner or face spanner (Fig. 7.39). In a pin spanner, the pins are made to fit into holes or slots and are used for turning.

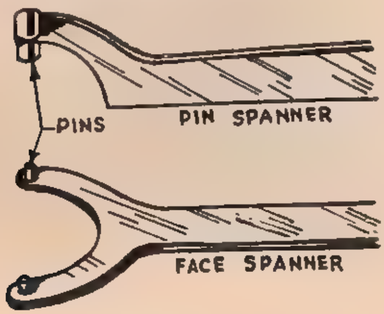


Fig. 7.39

The spanner works on the principle of lever. The length of the spanner arm has been designed to be comfortably used for transmission of torque for fastening or loosening. No pipe or additional piece should be used to lengthen the leverage, for that may break the spanner or shear the screw head.

PLIERS

Three types of pliers have been shown in Fig. 7.40. These are handy tools with different types of nose to suit the requirements. They are used for holding, twisting, turning, and pulling small jobs. They are also used for cutting small wires. They are made of steel and work on the principle of first system of lever.

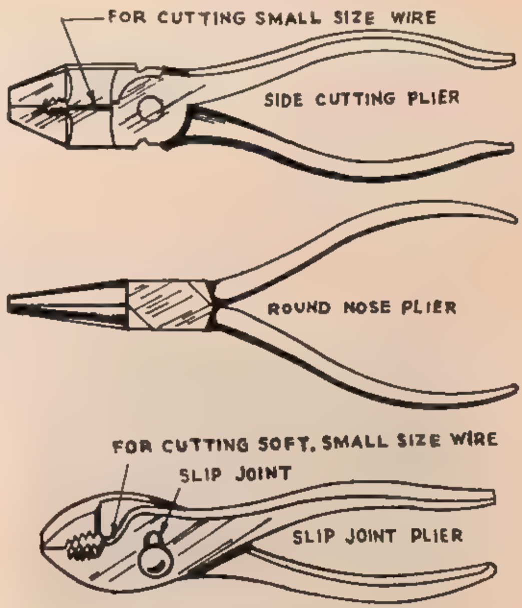


Fig. 7.40

7.9 Marking and Measuring Tools

Laying out in metal working means marking the dimensions on metal surfaces

with lines, arcs, etc. This is necessary when men working with machines or at benches have to remove the metal up to the lines or drill and tap at proper locations. This is nothing but a transfer of the drawing dimensions on the actual job.

Thus layout operations require tools for marking as well as for accurate measurements. Accordingly, some measuring tools can also be classified as marking tools. These marking and measuring tools are described together in this chapter. The important tools and accessories of this category are : (i) Surface Plate, (ii) Angle Plate, (iii) V-Blocks, (iv) Scriber, (v) Punches, (vi) Hermaphrodite Callipers, (vii) Dividers, (viii) Trammels (ix) Inside and Outside Callipers, (x) Try-square, (xi) Steel Rule, (xii) Bevel Protractor, (xiii) Combination Square, (xiv) Surface Gauge and (xv) Height Gauge.

SURFACE PLATE

Large flat surfaces are used as datum surfaces for measuring and marking operations. They are available in different sizes ranging from one foot square to as big as three feet by five feet (called marking table). These are made of cast iron and the surfaces are accurately finished flat by grinding or scraping (Fig. 7.41). Producing a surface plate is a skilled work which has already been described under scraping operation. A surface plate is placed horizontally on a strong table or concrete foundation and the setting is checked by spirit level. The finished surface should be carefully protected and should not be spoiled by rough handling or by dropping anything on the plate. After use, it should be oiled and covered by a wooden cover.

Fig. 7.41 Surface plate

ANGLE PLATE

This plate consists of two plane surfaces at right angles to each other. It is often used on surface plates or machine beds for clamping flat jobs with one of its flat surfaces (Fig. 7.42). It is made of cast iron and has different sizes.

Fig. 7.42 Angle plate

Fig. 7.43 Vee block

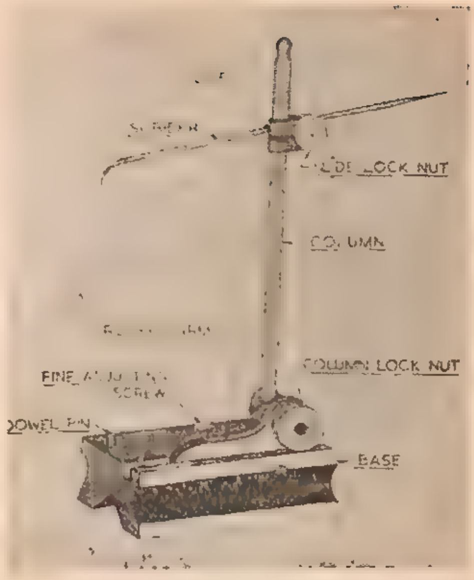


Fig. 7.44 Surface gauge

V-BLOCKS

This tool goes in a pair. The blocks have V-grooves on opposite faces and suitable clamping straps fitted on flat grooves on the sides. They are meant for the placement and clamping of round jobs. The side surfaces of a V-block are carefully machined so that they are at right angles to one another. Big V-blocks are made of cast iron and may not have clamping arrangements. Hardened and ground steel V-blocks are also in use (Fig. 7.43).

SCRIBER

This is a hard steel pin, sharpened to a point at both ends for scratching lines (Fig. 7.44). One of the ends is bent so that it can be conveniently used at places where the straight end cannot be used. This scribing tool may be used either directly or by being attached to a scribing block for drawing lines on metal surfaces.

PUNCHES

Punches are hardened tools, tapered and pointed at one of their ends. These are of two types : (a) prick punches and (b) centre punches (Fig. 7.45).

Prick Punches

The prick punches are used for making punch marks along the layout line, so that it remains visible during machining or fitting work. For accuracy, metal should be removed in such a way that the halves of the punch marks remain. Considerable practice is required to punch accurately and at regular intervals along the layout line.

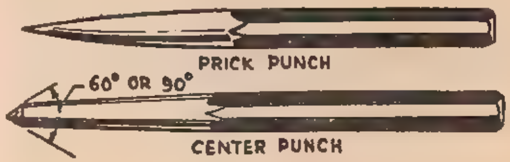


Fig. 7.45 Punches

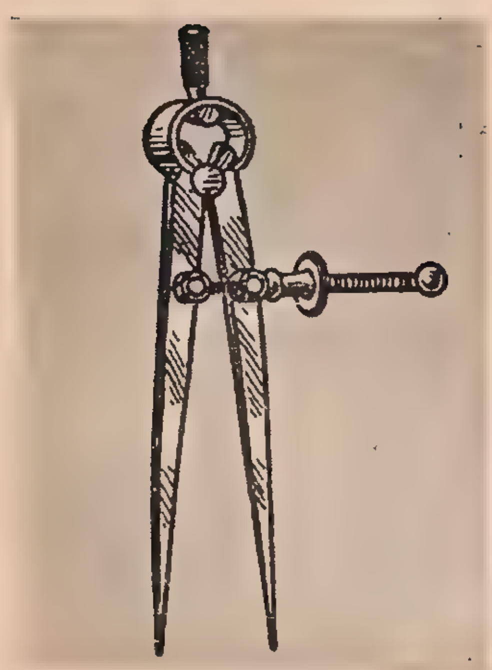


Fig. 7.46. Divider

Centre Punches

The centre punches are used for making deep indentation, so that they can initiate a drill point at a particular place accurately. The head of a centre punch is ground at an angle of 60° or 90°. The body is knurled for better grip. Bell punches are sometimes used for marking the centre of a round job. It consists of a conical bell through the centre of which slides a round punch which is used for marking.

DIVIDERS

This is a steel compass with hardened points at the end of two arms. This tool is used for transfering the distances from scale to the object and for scribing circles or circular arcs on metal surfaces. The size of a divider is indicated by the maximum distance it measures. The dividers may be plain or spring adjusted (Fig. 7.46).

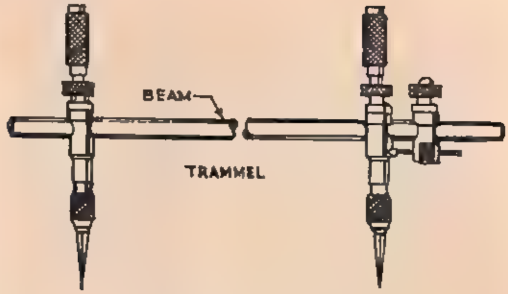


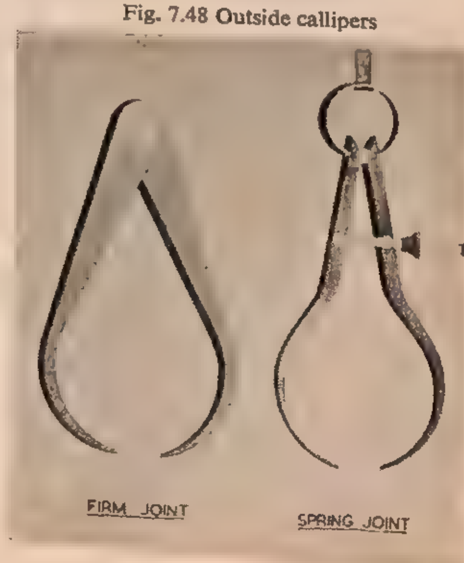
Fig. 7.47 Trammel

Sometimes plain dividers are provided with wings as spring dividers are. These wings make the dividers very convenient for use. The spring coil at the head of the dividers always keeps the arms open. For adjustment, a screw and nut arrangement is provided on the wings.

TRAMMEL

This measuring tool is used for large dimensions which cannot be measured with the other tools. It consists of a long and straight beam on which slide two blocks. These blocks hold two scribers (Fig. 7.47), one of which makes fine adjustment. This tool is also called beam compass or beam trammel.

Fig. 7.48 Outside callipers



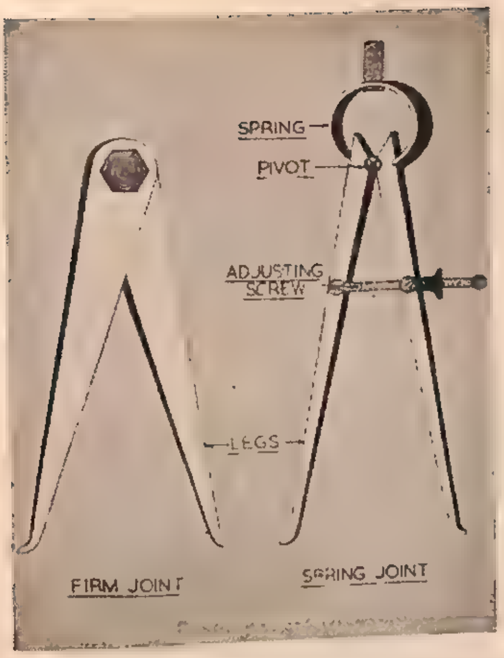


Fig. 7.49 Inside callipers

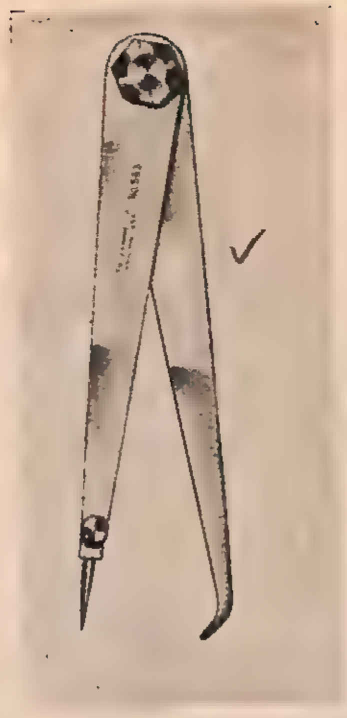


Fig. 7.50 Hermaphrodite callipers

CALLIPERS

These two-armed instruments are used for measuring linear dimensions. Outside callipers are used to measure outside dimensions of a solid (Fig. 7.48) and Inside callipers measure inside dimensions of slots or holes (Fig. 7.49). The two tips are carefully rounded in each type of the tool. Callipers may be either plain or spring loaded. The accuracy of measurement by a calliper depends on the feel of the operator. With this instrument, transfer of dimensions from scale or comparison with scale can easily be done. For very accurate measurement, outside and inside micrometers are used. Some of the techniques of measurement by a calliper may be observed carefully.

HERMAPHRODITE CALLIPERS

This tool with a scriber at one arm and a rounded calliper tip at the other is very useful for layout job. Its special use is in scribing parallel lines to the edge of a piece of work and in finding the centre of a round object (Fig. 7.50).

STEEL RULE

This is the standard of measurement used for ordinary metal working (Fig. 7.51). This rule is graduated in centimetres and inches. The minimum reading given is half a millimetre or one sixty-fourth of an inch. It is made of steel and is available in various sizes from 6″ to 4 ft. The

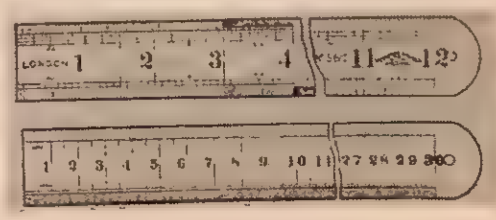


Fig. 7.51 Steel rule

common sub-dividions of inches are 1/2″, 1/4″, 1/8″, 1/16″, 1/32″ and 1/64″. In the C.G.S. scale they are 1/2 mm., 1 mm., 5 mm., and 10 mm. or 1 cm. It is sometimes used as a straight edge for an ordinary work. Sometimes a hook is fixed at the end of a steel rule to take measurement right from the end.

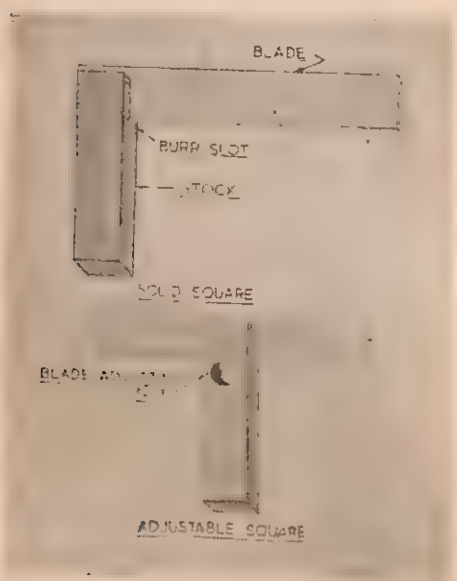


Fig. 7.52 Try-square

TRY-SQUARE

This instrument is made for checking right angles. It consists of a beam of rectangular section and a thin blade with or without graduations. If the blade is fixed, it is called solid steel try-square and if it is sliding, it is called adjustable try-square (Fig. 7.52). The precision square is known as the master square which is generally used for reference. As the squares are liable to wear and errors creep in after long use, the master square is used for their checking. There is always an under-cut on the beam at the corner, so that it gives relief to any dirt or burr at the corner of the right angled surface which is checked.

The blade is sometimes bevelled for better reading.

BEVEL PROTRACTOR

This tool is used for measuring angles. It is made of a round base with a projected and slotted beam. Another piece rotates inside the base and holds an adjustable blade. The angle between the beam and the rotating blade is given in degrees on the scale. Sometimes there are vernier arrangements for accurate reading (Fig. 7.53). For further precise reading, the scale may be fitted with a lense for magnification. This is called an optical bevel protractor. Ordinarily, bevel gauges are used. These gauges are compared with a bevel protractor for the reading of angles.

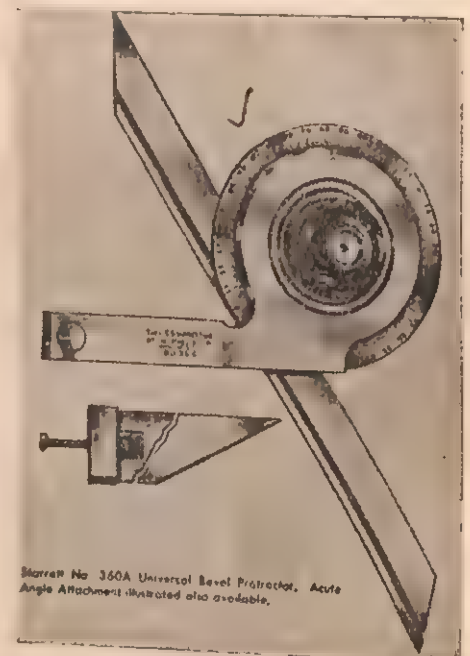


Fig. 7.53 Bevel protractor

COMBINATION SQUARE SET

This is a very common instrument used in metal working shops. This is a set of :

a) one bevel protractor with a small

spirit level fixed on it,

b) a square head with a spirit level fixed on it,

c) a centre head,

d) a graduated steel rule with a notch to slide through the three heads mentioned above.

This set (Fig. 7.54) is used as an angle measuring instrument, as an adjustable square for marking centre lines in round objects, and for extending corner lines.

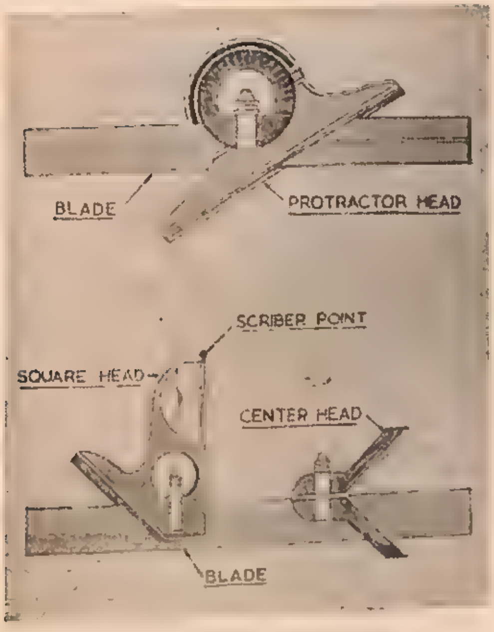


Fig. 7.54 Combination set

SURFACE GAUGE

This instrument is commonly used for marking and is known as marking block (Fig. 7.44). Its heavy flat base has arrangements for holding an adjustable block. The screw is used for fine adjustment. The block holds a spindle through a joint so that the spindle may be set at any angle. A universal joint slides on the spindle and carries a scriber which is also rotatable. So the whole arrangement makes the scriber end move up and down and reach certain distances for scribing lines. The base has a V-groove below, so that it can rest on round pieces. The dowel pins are fixed on the base, and they can be projected in such a way that the surface gauge base may be made to guide along the edge of a straight surface.

VERNIER CALLIPERS

This instrument is a precision type callipers used for measuring both outside and inside dimensions up to .001 inch or .02 cm. by means of vernier arrangement (Fig. 7.55). The steel beam is graduated and has the fixed jaw at one end. The slider slides on the beam and has a mating jaw; it also contains the vernier scale.

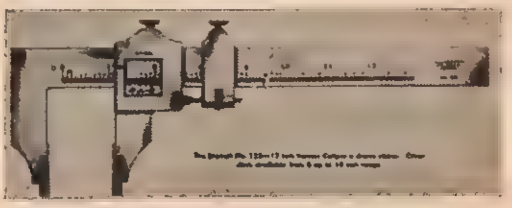


Fig. 7.55 Vernier callipers

When the jaws touch each other, they are perfectly flat and coincide. In this closed position the main scale and vernier scale both read zero. The jaws are radiused outside to be used for measuring inside holes. The widths of the jaws which are constant are added to the readings of the instrument. The beam is generally graduated on both sides, one in the F.P.S. and the other in the C.G.S. system. In the main scale, an inch is divided into 40 main divisions, each division measuring .025″. Now the vernier has 25 divisions to coincide with 24 divisions of the main scale. The vernier constant is given by (25-24) x $\frac{1}{40 \times 25}$ = .001″. In the metric scale also the vernier cost is ·01 mm.

The common sizes available of this tool are 9″, 12″ and 28″.

VERNIER DEPTH GAUGE

The principle of measurement with this instrument is the same as that with the vernier callipers. The block has the vernier scale and the main scale (beam) slides. This is a very useful precision instrument for measuring depth. The sizes available are from 6″ to 12″.

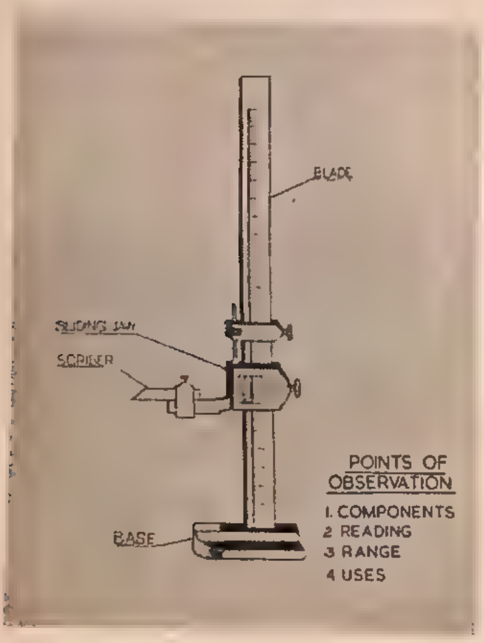


Fig. 7.56 Vernier height gauge

VERNIER HEIGHT GAUGE

This instrument is nothing but a graduated beam standing on a solid base (Fig. 7.56). The slider blade on the beam has the vernier scale and it has a scribing bid attached to it. It works according to the same principle as the callipers. This instrument is used for very accurate layout jobs. In place of the sharp point of the scriber, the scribing bib has a sharp line formed by the taper angles. Whenever the bib gets blunt, it is ground on taper and not from base. Evidently the edge should be very fine, as the instrument measures up to .001″. The size of the instrument may be anything between 12″ and 18″.

MICROMETRE

This instrument is also used for fine measurements up to .001″ or .02 cm. It works on the screw and nut principle. The screw has 40 T.P.I. for an inch-micrometre. The lead is 1/40″ = .025″; as a screw rotates in a nut, it advances .025″. Now, the screw has 25 circular divisions in one complete circle. So each circular division equals .001″, or, in other words, the least count of the micrometre is .001″. Similarly, in the C.G.S. system, least count is ·01 mm.

The micrometre is a misnomer, for, according to the name, it should measure a micrometre, i.e., 10^{-6} metre (=.000001m) or .0001 cm. which it never does. Micrometres are of three types: (a) outside

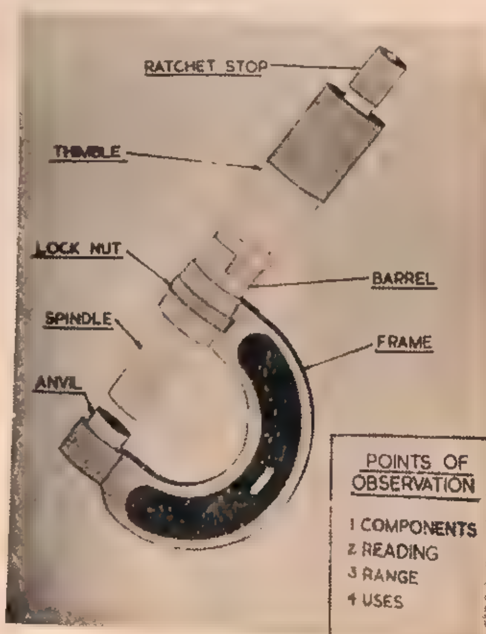


Fig. 7.57 Outside micrometre

micrometre, (b) inside micrometre, (c) depth micrometre.

Outside Micrometre

This type of micrometre is used for measuring the width and thickness of flat jobs and outside diameters of round pieces. It consists of a body, a barrel, a thimble spindle, a sleeve nut and an anvil (Fig. 7.57). The body is C-shaped with a barrel fixed at one end. A sleeve nut is pressed inside the hole. The nut has a split tapered end, screwed outside. A small nut is placed at this end for adjustment of any play of threads. The barrel lies fixed on the spindle. The spindle moves through the sleeve nut and projects through the body and meets the anvil. The anvil is pressed at the other end of the body. Both spindle and anvil are hardened and lapped so that their end surfaces mate very accurately. Sometimes the barrel end is fitted with a ratchet and spring. In an inch micrometre the barrel is divided into ten big linear divisions, each divided into four small divisions. Again, the barrel is divided into 25 equal circular divisions.

So, as explained above, the least count is .001″. But sometimes the help of the vernier is taken for further precision measurement. Above, the linear scale barrel is divided into ten circular divisions which correspond to nine circular divisions of the thimble and this gives the vernier constant which is equal to 1/10 of the least count, i.e., .0001″. The size of an outside micrometre is given by the maximum length it can measure. The sizes available are 1/2″, 1″, 2″, 3″, up to 12.″ Micrometre sets in which only one micrometre spindle is used and the anvils are changed to suit a job length are also available. A standard is supplied along with every set.

Use of Outside Micrometre

When a micrometre is taken for measurement, first the zero error is checked. The operator has to see that the zero of the main scale coincides with the zero of the circular scale when the anvil and the spindle coincide. This should be tested after cleaning the anvil and the spindle faces by passing a piece of clean paper or cloth under a little pressure from the spindle screw. Hard pressure on the screw gives a false reading. It should be noted whether this error should be added to or subtracted from the reading. Then the micrometre is used to measure a test gauge. Test gauges are standardized and have very accurate dimensions. For a 1″ micrometre, a 1″ test gauge should be used; for a 2″ micrometer, a 2″ test gauge and so on.

The holding of this micrometre is very important. The pressure on the spindle

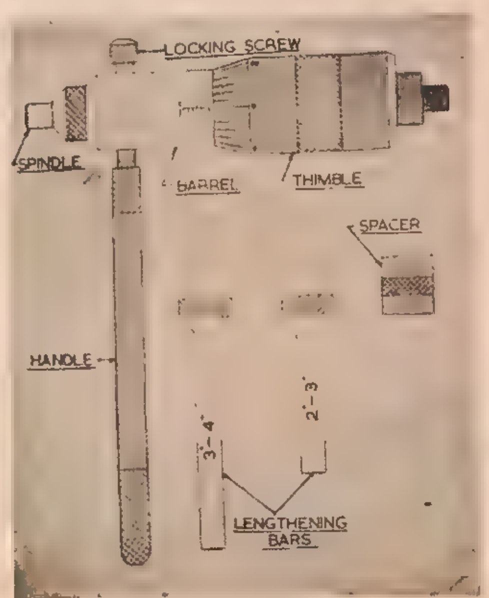


Fig. 7.58 Inside micrometre

while taking the measurement is called the feel, which is given by rotating the knurled

thimble by thumb and fore-finger. This touch or feel varies from person to person and so different persons may get different measurements for the same job with the same micrometre.

The ratched micrometre is of greater help for precise measurement. With this instrument, the pressure of measurement is the same in all cases. The different ways of measuring by micrometre may be observed carefully. The screw-thread outside micrometre is used to measure the effective diameter of screw threads. The anvil face has a thread form to mate with the thread of the screw to be measured. The spindle has cone with a radius like the actual thread form of a nut

Inside Micrometre

This instrument (Fig. 7.58) works on the same principle as the outside micrometer and is used for measuring inside diameters. It is available in 1/2″ to 24″ sizes and is supplied in a set. The set consists of a micrometre head and several interchangeable sticks with collars. A handle can be fitted to it for measuring deep holes. It requires practice to get the accurate feel and to learn techniques of using this instrument for correct measurement.

Depth Micrometre

It consists of a flat based block with a graduated barrel which has a sleeve nut. The spindle passes through the barrel. This instrument is very useful for measuring precisely the depth of a hole and a slot. The maximum size in which this instrument is available is 6″.

7.10 General Procedure of Layout

(a) The most important thing is to understand thoroughly the blueprint and to see carefully that all dimensions are given. (b) To find out the overall and the principal dimensions of the job so that the job may not fall short of dimensions. (c) To select the datum surfaces and decide the steps of marking. (d) To prepare the surface of the job where markings are to be made legible and visible. Surfaces may be rough or machined. Generally chalk is rubbed or white paint is brushed over rough surfaces. In case of machined surfaces, copper sulphate can be used only on iron whereas the colouring die can be used on any material. The machined surface is cleaned, free from grease and spread over evenly with copper sulphate solution applied by a piece of rag. As it turns red, a drop of oil is poured and the surface is rubbed, otherwise by further action it becomes black. The operation should be carefully done, for copper sulphate solution corrodes tools and instruments. (e) To arrange tools and jobs on a surface plate or marking table. (f) A scale on a stand or a combination square may be used for taking measurement. (g) A surface gauge is used to draw lines parallel to the surface plate. (h) The job is turned at right angles and parallel lines are drawn again. (i) Each position may be located as in rectangular co-ordinates and at different places. (j) A prick punch is used to mark dots lightly and uniformly. (k) Drill hole centres should be deeply centre puched. A few circles smaller and one circle slightly bigger than the drill diameter should be laid out. Small circles are used for checking the centre position, the bigger circle for checking the location of the final hole. All checking is done by eye estimation which is accurate to a considerable degree.

The job is now ready for fitting or machining operation. A thin job should be clamped against an angle plate. In case datum surfaces are not available, one

has to machine or file two perpendicular surfaces to get the datum surfaces.

Combination squares can be conveniently used to lay out parallel lines on a job having two flat perpendicular edges. The knowledge of geometrical construction should be used for layout whenever possible.

To mark a machined round job on its faces, the operator should place the job on V-blocks. Callipers may be used to find its centres. The surface gauge can also be used to draw parallel lines as close as possible by turning the object through 180° till the lines coincide. This will give the centre line. The two centre lines will intersect at a point and thus the centre is found.

In drawing perpendicular lines on the face of a round object, the object is clamped on the V-block and through the block at 90°.

Precision Layout

This is done generally on machined surfaces with close tolerance. So a height gauge is used. The object must have two perpendicular datum surfaces. The scriber of a height gauge does not reach the surface plate, so the object is placed on a parallel bar with one of the datum surfaces on it. The height of the top face of the parallel bar is to be found out by placing the scriber bib on it and by feeling. Thus the height of the datum surface is found. Now layout can proceed as before.

WORDS TO KNOW

Fit, Nominal Size, Basic Size, Limits, Tolerance, Allowance, Vice, Hammer, Chisel, Saw, File, Snips, Shears, Drills, Scraper, Thread, Taps, Dies, Trammels, Vernier, Least Count, Vernier Constant.

QUESTIONS

What is the fitting operation?
What are the specific jobs of fitters?
How are fitters classified according to their trades?
What are the common types of fit? Explain their significance.
How does one type of fit differ from any other? What are the common terms used in fits?
Name some of the hand tools used commonly by a fitter.
How do you classify tools in a fitting shop?
What are the specific purposes of hand tools? Explain by means of sketches the use of a vice.
What are the common types of vices used in shops?
Describe the different types of gripping arrangements.
What is the approach to the design of a striking tool?
Name and sketch some of the striking tools.
What are the characteristics of a cutting tool?
Describe a few cutting tools of a fitter and the way they are used.
Sketch the different types of chisels and discuss their use.

Write in detail the chiselling operation.
What is a fitter's file? How are files specified?
Describe the operations with a file. What is the importance of posture and pressure in a filing operation?
What are cross filing and draw filing?
How is a filed surface tested?
How do you select files for a job?
Sketch a scraper showing the cutting edges. Why is scraping done?
How do you scrape a surface plate?
What is the function of shears? Why are shears of different shapes in use?
What is a saw and how is it fixed to the frame?
What care should you take while sawing thin sheets?
What are the different types of power saws available?
What is a thread? How are threads made?
What are the elements of a thread and how are they specified?
What is meant by a multi-start thread?
Describe some tools used for outside and inside threading?
How do you make a tapped hole?
What precautions will you take to make a blind tapped hole?
What are the different assembly tools used by a fitter?
Name the common tools used for marking and measuring in a fitting shop.
Discuss the uses of a surface plate, an angle plate and V-blocks. How are try-square and combination square sets used?
What is a surface gauge and how do you use it for marking in shops?
What is a vernier? How do you find out the vernier constant of vernier instruments?
What is the least count of a micrometre?
How do you measure correctly with a micrometre?
What is the general procedure for laying out a job?
Explain the different methods of finding the centre of a round job.
Describe the procedure of precision layout.

CHAPTER 8

Machine Shop

8.1 Machine Shop

Machine shop is the heart of a workshop. It is an enclosure inside a workshop or factory where machine tools are installed. These tools are electrically powered and are used for machining various types of components for articles of general and engineering use. Groups of similar machines are arranged in bays, such as drill bays, lathe bays, etc. (Fig. 8.1). For mass production, i.e., for production of a repetitive nature, machine tools are arranged in the order of operation to be performed. For saving space, production lathe machines are often arranged at an angle instead in a line.

8.2 Transmission in Machine Shop

The transmission in a machine shop is done either by line-shaft transmission or by individual motor transmission. The former method is outdated. Modern machine tools are all self-motored.

LINE SHAFT TRANSMISSION

In this transmission a group of machine tools is powered from a centralized motor through the line shaft (Fig. 8.2). The main motor of a high horse-power rotates a big pulley at the end of a long line shaft by means of a flat belt or chain drive. The line shaft rotates on bearing within plummer blocks. These blocks are held up by brackets.

The line shaft is connected to a number of countershafts, and one countershaft transmits power to one machine tool. A countershaft has at one end a fast and loose pulley, the belt position on which can be controlled by a long lever. The other end of the countershaft has stepped fixed pulley, matching the stepped pulley of the corresponding machine tool. Generally, flat belts of canvas or leather are used. The ends of belts are joined by alligator joints and pins.

INDIVIDUAL MOTOR TRANSMISSION

Generally, the electric motor has a pulley at the end of its shaft. The pulley has several grooves for endless V-belts. There is a corresponding pulley at the end of the shaft of the machine tool. From this driving shaft motion and power are transmitted to various parts of the machine tool through a train of gears. Sometimes an electrically powered motor directly drives the spindle of a machine tool. For circulation of coolants, often a separate pump and motor is used.

8.3 Machine Tools

These are electrically powered tools, the main objective of which is to remove a portion of an object so as to give it the desired shape. They are designed to produce surfaces of proper smoothness and definite dimensions at the minimum cost.

8.4 Classification of Common Machine Tools

Common machine tools are classified according to : (i) the types of surface they produce and the general arrangements in the machine tools to produce them, (ii) the types of cutting agents used, and (iii) the purpose for which they are used.

(i) Machine tools generally produce plane, cylindrical and helical surfaces. Shaper, planer, and miller are machine tools for plane surfaces, while lathe, and drill are for cylindrical and other surfaces of revolution. A drill machine produces holes, i.e., internal cylindrical surfaces and a lathe machine produces both holes and external cylinders. Cones, flats, helical and other types of surface of revolution are also produced on lathe. A milling machine produces gears, cams, etc., which have more complicated surfaces, and flats which have simpler surfaces. General arrangements of the bed, the table, the body, the spindle and the transmission sometimes determine the characteristics of a machine tool. These are to be observed very carefully and the nomenclature of common machine tools has to be remembered from this point of view.

(ii) There are mainly three types of

Fig. 8.1 Lathe bay

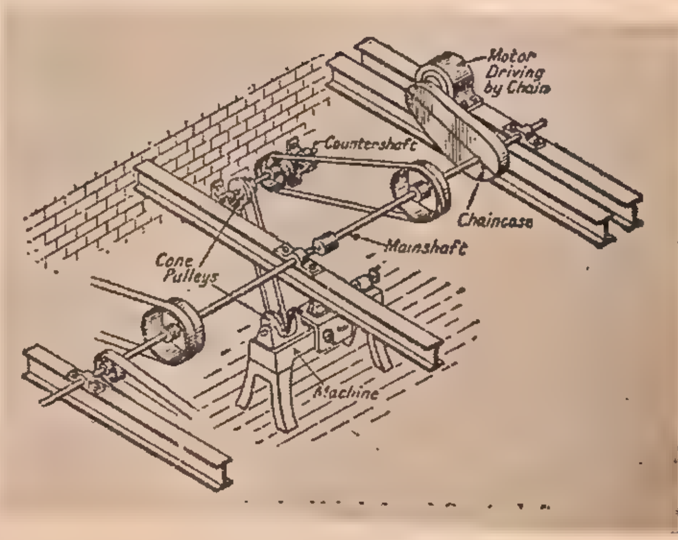


Fig. 8.2 Line-shaft transmission

cutting agents or tools used in machine tools. These are single-point cutting tools, multi-tooth cutting tools and abrasive grinding wheels. Machines using single-point cutting tools are lathe, shaper, planer, etc., and machines using multi-tooth cutting tools are milling machines, gear cutting mechines, etc. All types of machine tools using abrasive grinding wheels are called grinders.

(iii) Machine tools classified according to the purpose for which they are meant are: (a) single-purpose machine tools, such as drilling, slotting, surface grinding etc; (b) multipurpose machine tools, such as universal milling, centre lathe, capstan lathe, etc.; and (c) special purpose machine tools, such as profile turning machine, crank shaft grinding machine, etc. The last group of machine tools is a highly specialized one and is used for a specific purpose for production.

8.5 Lathe

Lathe is a machine tool to produce mainly cylindrical surfaces by machining. This is done by rotating the object about a fixed axis and by removing material as chips with the help of a sharp tool having a point cutting nose. The tool is fixed on a tool post and is made to proceed parallel to the axis of the rotating object. Thus cylindrical surfaces are produced on the object, externally or internally. Lathes are also known as turning machines and the operator is called a turner or a latheman. Besides cylindrical surfaces, plane, conical and helical surfaces are also produced on a lathe. As the lathe is power driven, it is sometimes called the engine lathe (Fig. 8.1).

History of Lathe

In the earliest type of lathe, the rotational motion was used to be given by wrapping and unwrapping a rope round the object. The method is used even now by the carpenters of our country in small scale industries for wood working lathe. A strip of wood or 'lath' was used to support the rope and from this 'lath', the name 'lathe' for a turning machine may have been derived.

An Englishman, Henry Maudsley, designed and built a lathe in about 1797. This could produce screws having 16-100 threads per inch. Within thirty years lathes of 9 ft. turning capacity were built which were used to bore large cylinders and turn big fly wheels. This made it possible in those days to build steam boats and locomotives.

8.6 Classification of Lathes

Broadly lathes can be classified into two main groups: general lathe and production lathe. When a lathe is so designed as to do a variety of jobs of a simple nature we call it a centre lathe. This is the most versatile machine tool but cannot be used in mass production. The other class of lathe is used for quantity production. This class includes capstan, turrets, automatics, etc. Generally in a centre lathe sliding, surfacing and screw-cutting operations are done and as such it is known as S.S.S.C. lathe. Mass production lathes are beyond the scope of this book.

8.7 Different Parts of a Lathe

BED

The main body of a lathe is called the bed, which is supported on legs of a suitable height. A bench lathe has smaller legs and is placed on a bench or cabinet during operation. The bed of a lathe is usually

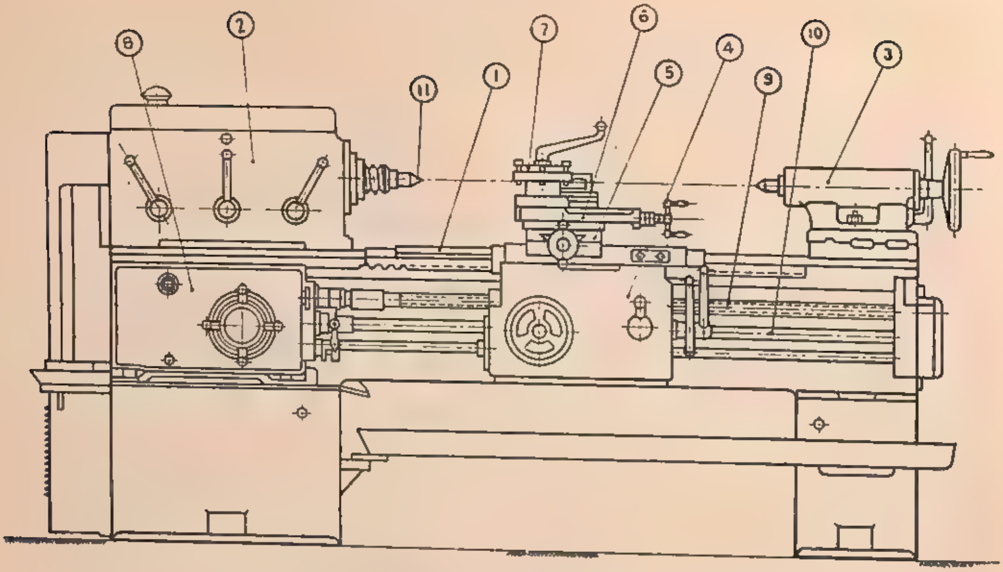


Fig. 8.3 Lathe
1. Bed 2. Headstock 3. Tailstock 4. Carriage 5. Cross-slide 6. Hand slide 7. Tool post 8. Feed gear box 9. Lead screw 10. Feed rod 11. Spindle

cast integral with the legs. It is used to support other parts of the machine tool and to resist cutting forces. So it has to be rigid enough not to yield, otherwise it vibrates causing inaccuracies in the job. Moreover, the bed provides accurate alignment to the headstock, the tailstock and the cross-slide and offers precise guidance to the tailstock and the cross-slide.

The sections of a lathe bed are shown in Fig. 8.4. On the top surface it has generally two pairs of machined guide surfaces called 'ways', either ground or finished by scraping. The outer pair is used for guiding the carriage and the inner pair for guiding the tailstock. The most common material used for this is special cast iron. For long term accuracy, the beds or bodies of all machine tools, including those of precision lathes, should be seasoned for some years.

One type of lathe has a gap in the bed in front of the headstock to accommodate objects of large diameters and short lengths. This is known as a Gap Bed lathe.

HEADSTOCK

This part of a lathe machine encases the driving arrangements and drives the object. It is positioned on the bed and is always on the left hand side of the operator for convenient working.

The body is of cast iron and has accurate machining positions for the seating of bearings. The bearings support the spindle of the machine and other shafts for transmission gears. The spindle is hollow and has a standard inside taper at the front end. The front end has also suitable outside machined surfaces to register and fix chucks and other holding arrangements for jobs. Slide bearings as well as ball and roller bearings are used in the headstocks of machine tools. Suitable arrangements are made for the lubrication of these bearings and gear meshings.

In a lathe having stepped cone pulley drive, the headstock often has back gear arrangements, as shown in Fig.8.5, for the reduction of spindle speeds. The back gear

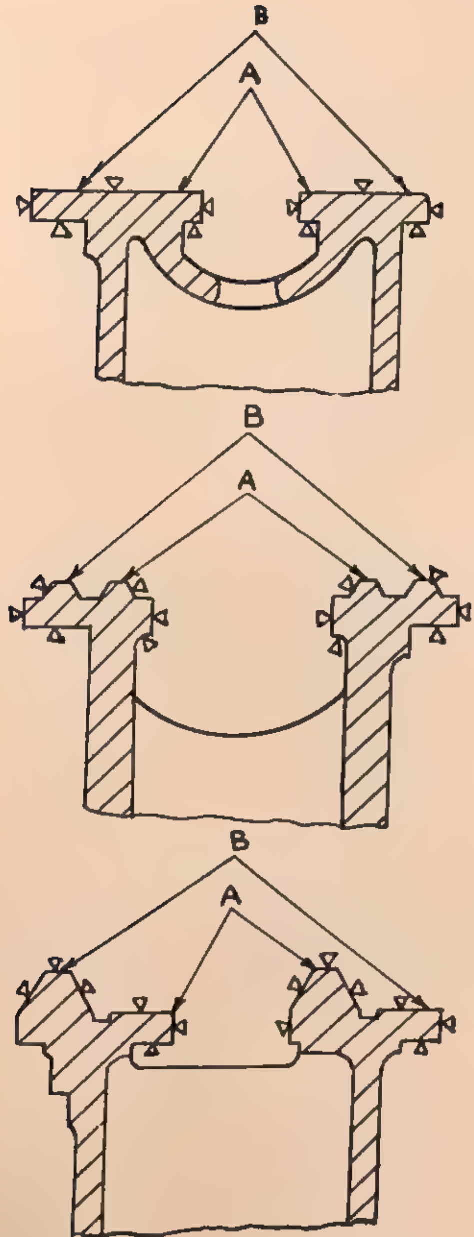


Fig. 8.4 Sections of a lathe bed

set is on a shaft with eccentric mounting. The locking pin E is to be disengaged so that the main spindle is made free from the direct gear and the back gear is engaged as A to C and B to D.

Most modern lathes, and other machine tools have all geared type headstocks (Fig. 8.6). Here the drive is obtained from an electric motor which is connected by V-belts to the pulley at the end of the driving shaft. This shaft carries a clutch and a cluster of gears, which mesh with other gears on spindles. Ultimately the motion and power are transmitted to the spindle of the lathe. There are levers to mesh different sets of gears to obtain different spindle speeds of the lathe.

CARRIAGE

The function of the carriage of a lathe is to hold the cutting tool and give it suitable motions for operation. It is a complete assembly consisting of the saddle, the apron, the cross-slide, the compound slide and the tool post.

SADDLE

This is the portion of the carriage which rests on the bed of a lathe. It is made of grey cast iron. It has two ways below to fit the outer pair of guides of the bed, so that it can move along the bed parallel to the axis of the spindle of the lathe. On the top side of the saddle there are dove-tailed Vee guides, perpendicular to the main guides of the bed.

APRON

This is a cast iron piece hanging from the saddle in front of a lathe. It encases all mechanisms for transmission of power and motion from the feed shaft and lead screw to the carriage and the cross-slide. There are a few handles to control the transmission. The carriage and the cross-slide can also be moved manually.

CROSS-SLIDE

This piece is of cast iron and rests on the saddle. It has also dovetailed Vee

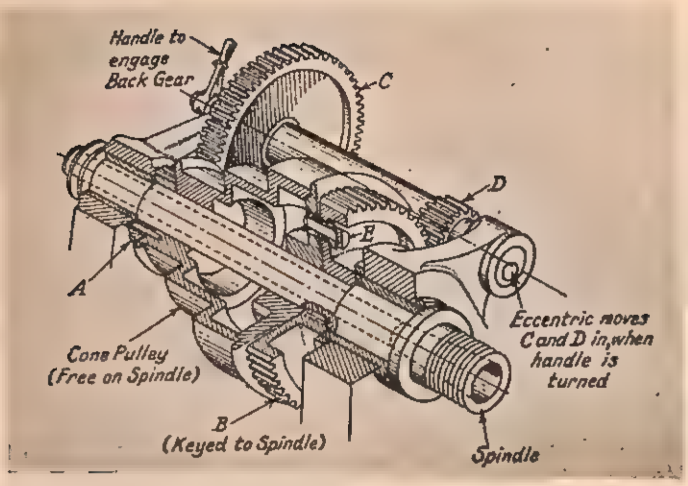


Fig. 8.5 Back gear mechanism

guides to fit their counterparts on the saddle. Gib strips are used for precise adjustment of fittings of guides and for compensation of wear. The movement of the cross-slide is given by a nut and screw arrangement. The screw is generally of acme type. At the end of the screw a graduated sleeve has been attached so that positioning of the cross-slide can be done

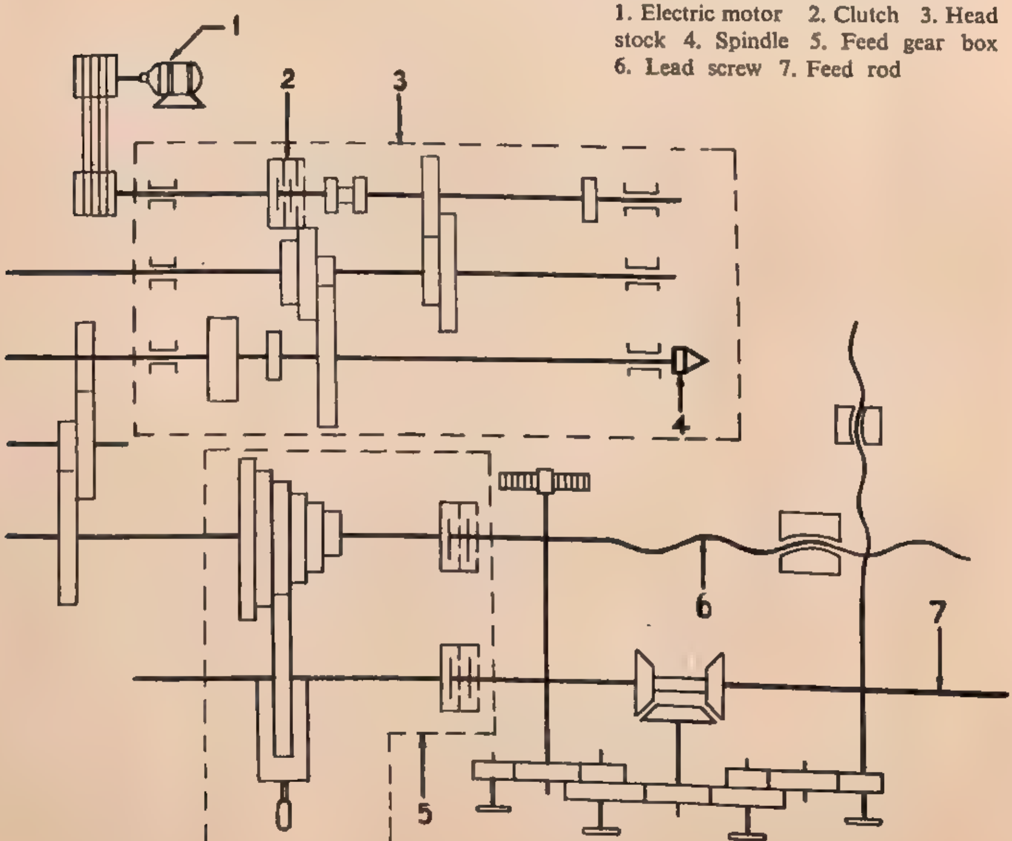


Fig. 8.6 Geared headstock of a lathe
1. Electric motor 2. Clutch 3. Head stock 4. Spindle 5. Feed gear box 6. Lead screw 7. Feed rod

accurately. This helps to give accurate depth of cut. As it gives horizontal movement perpendicular to the main slide, it is called the cross-slide. The carriage gives a 'sliding' movement to the tool along the bed, whereas the cross-slide gives 'surfacing' movement across the bed. The latter is called the 'facing' operation in a lathe.

COMPOUND SLIDE

This is attached to the upper face of the cross-slide and carries the tool post. It has both sliding and rotating movements. The sliding movement is given by a nut and screw arrangement. The rotating movement is given by a graduated swivel base. So the tool can be slid and kept at any angle round a vertical axis. This is a manual operation. A useful application of the compound slide is in the production of short tapers.

TOOL POST

This is a gadget used for holding a single-point turning tool on the carriage. Various types of tool posts are seen. The four-station type square tool post, known as 'square turret tool post', is generally used in modern centre lathes for holding four tools at a time.

FEED SHAFT

This is used to transmit feed motion from the main machine spindle to the carriage and cross-slide. To have different feeds, the motion is transmitted through a set of gears. In modern machine tools a separate feed gear box is provided to give a wide range of feed rates.

LEAD SCREW

This is a precision screw of acme type and connects the motion of the main spindle to that of the carriage. A moveable half nut in the apron is used to engage and disengage the connection of carriage to the lead screw. For easy engagement, the acme type of thread is used. The lead screw is used only when threads are cut.

TAILSTOCK

It is the counterpart of the headstock. It is positioned on the right hand end of the bed facing the headstock. The construction is shown in Fig. 8.7. The barrel has a morse tapered end to accommodate the dead centre. The function of the tailstock is to support the job on the centre at its end. The axis of the tailstock is precisely collinear with the axis of the headstock. The object is supported on its centre at the other end by the headstock. The axis passing through these two centres supporting the job becomes the axis of the surface of revolution. The tailstock is also used for drilling, reaming and sometimes screwing operations. The main body has two parts: one, the bottom part that has ways below to fit the inner pair of guides of the bed of the lathe machine and two, the top portion that can be adjusted transversely relative to the base. For accommodating jobs of different lengths, the tailstock can slide on the bed and can be locked at different positions of the bed. It is also used for turning taper on long jobs.

8.8 Job Holding Arrangements on a Lathe

HOLDING ON CENTRES

The driving plate is fixed on the spindle nose, which rotates the object through a lathe dog or carrier. One type of carrier is shown in Fig. 8.8.

HOLDING BY CHUCKS

All chucks have jaws which are operated either (i) independently or (ii) all at a time

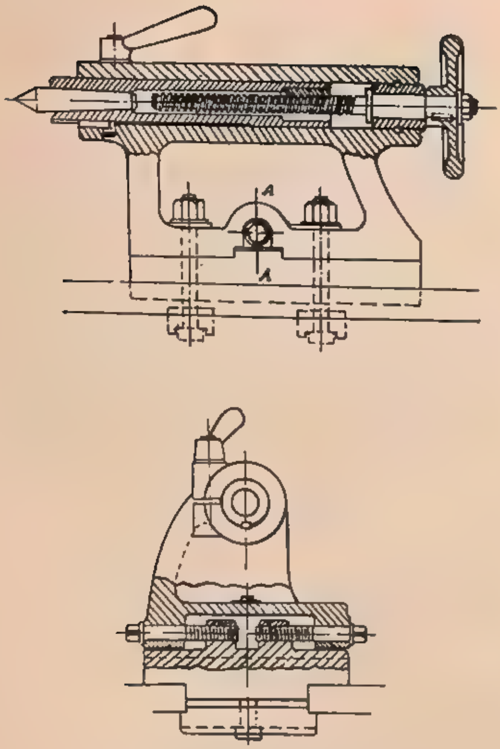


Fig. 8.7 Tailstock of a lathe

Fig. 8.8 Carrier of a lathe

Self-centring chuck

by one control, i.e., by rotating one key. They are named accordingly.

Independent chucks have four jaws working the screw and nut system, as shown in Fig. 8.9. Square threaded screws are generally used.

The self-centring chucks have generally three jaws or two V-type jaws. Generally the jaws are actuated by rotating a scroll (surface spiral thread) by means of a key. The jaws simultaneously hold a pre-machined object concentrically. Sometimes self-centring chucks actuated by cams are also used.

FIXING JOBS ON FACE PLATE

Sometimes odd jobs are fixed directly or by means of an angle plate on the face plate of a lathe. The face plate is a rather

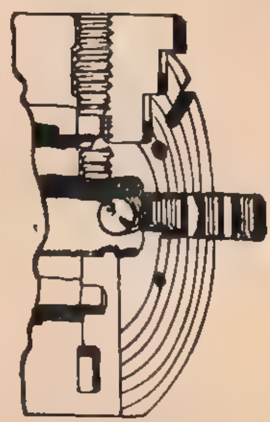


Fig. 8.9 Independent chuck

big circular plate fixed on the nose end of the spindle and it has several slots for fixing bolts.

HOLDING BY COLLETS

Collets are often used in lathes, specially in production or small precision lathes, for holding cylindrical objects of small diameter. Generally they work on the taper cone system. Common types of collets are shown in Fig. 8.10.

CENTRES

A dead centre is a solid body with the point supporting end having a cone of 60°. The tail-end of the centre is ground taper to suit the tailstock nose. As it remains steady during operation, it is known as the dead centre. The one used in the head-stock has a 60° point cone and is called the live centre, because it rotates during operation. This centre is also ground tapered to suit the tapered nose of the headstock.

Fig. 8.10 Collet chuck set

Another type of centre used on the tail-stock revolves or rotates along with the object. So there is no relative movement between the centre and the object and, consequently, no friction. The revolving arrangement is made by means a ball bearing in the casing. In some operations the head of the tailstock center is halved to accommodate the cutting tool to proceed near the centre of the object. It is called half centre.

STEADIES

Steadies are generally used to support long slender round bars when they are turned on a lathe or are machined at the end face. The steadies have adjustable jaws on a cast iron frame with a suitable fixing base. The three-jaw steadies are fixed on the bed of a lathe and are known as stationary steadies. The frame is provided with a hinge to accommodate the job. The steady is a stationary support to the job when the operation is on.

The travelling or moving steady is fixed on the carriage and moves along with the object during operation. It has only two supporting jaws, which travel on the machined surface of the object. The purpose of all steadies is to give support to a long slender object, so that it may not deflect while rotating and being acted on by the cutting forces.

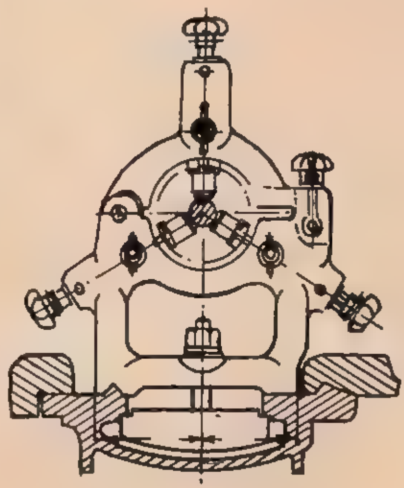


Fig. 8.11(a) Stationary steady

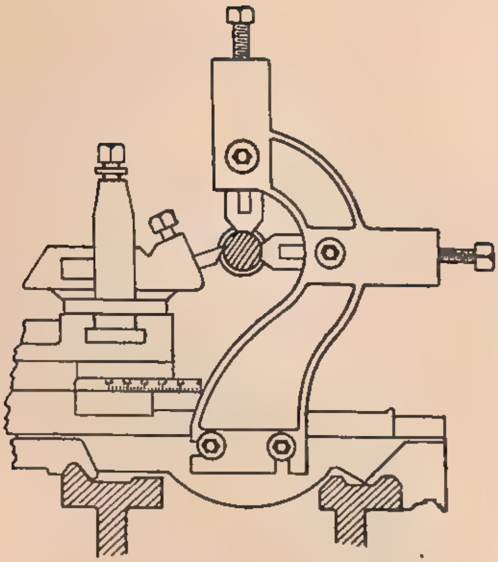


Fig. 8.11(b) Moving steady

8.9 Cutting Tools and Tool Holders

For efficient and accurate operation, it is essential to have the following:

1. Correct type of turning tools,
2. Rigid support,
3. Proper geometry of tools,
4. Suitable hardness and strength of tools.
5. Correct setting.

Types of single-point tools available for work on lathes:

(a) Solid tools,
(b) Tool bits to be used with tool holders,
(c) Tool tips fixed on shank.

The common tool materials are:
High carbon steel: 0.9-1.3 per cent carbon, rest iron.
High speed steel: 14-22 per cent tungsten together with small percentages of chromium, vandium and cobalt.
Cemented carbide (non-ferrous type): Tungsten, titanium and tantalum carbides are used separately or together with cobalt as binding agent.
Stellite (non-ferrous type): 50 per cent cobalt together with varying percentages of molybdenum, chromium, vanadium and carbon. These are cast tools.

Fig. 8.12 gives the nomenclature of the tools and the names of the angles. The face on which the cut material skids out is the rake face and the face below this is called the flank face.

The main angles and contour which are ground on the tool cutting edge are back rake angle, side rake angle, side clearance angle, front clearance angle, approach angle and nose radius.

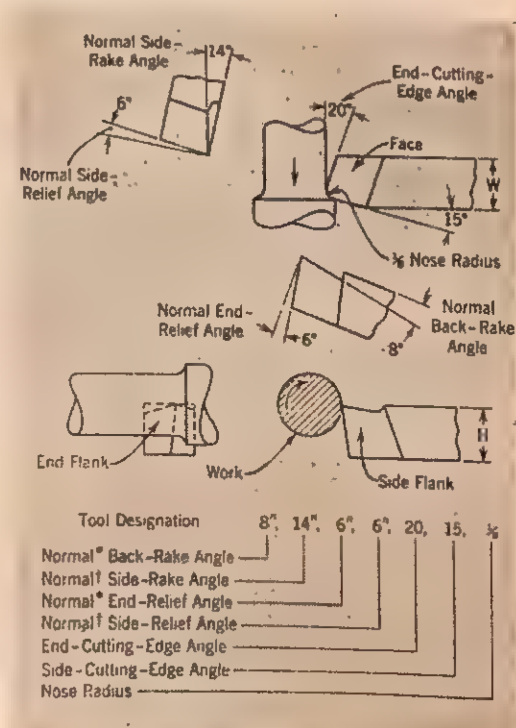


Fig. 8.12 Nomenclature of tool geometry

These angles and radius vary according to the nature of cutting, the work material, the tool material and the finish required.

Table 8.1 shows the general angles ground on tools for some common materials.

Table 8.1 General Angles Ground for High Speed Steel Tools

Material to be cut	*Back rake (degrees)*	*Side rake (degrees)*	*Side clearance (degrees)*	*Front clearance (degrees)*
Mild steel	18-20	18-20	6-10	8-10
High carbon steel	6-10	6-10	6-8	6-8
Cast iron	5-10	7-10	6-10	8-10
Brass	0-5	0-5	6-8	6-8
Aluminium	25-40	15-20	8-10	8-10

TOOL HOLDERS

Tool holders for tool bits are generally forged and suitably machined to accommodate and lock bits of proper size (Fig. 8.13). Tool shanks for tool tips are fixed on machined mild steel shanks. The high speed tips are brazed or butt-welded with shanks. The carbide tips are brazed or clamped.

Tool holders are right hand tool holders or left hand or straight tool holders as they are bent right or left or they remain unbent when fixed on the tool post.

Fig. 8.13 Setting of lathe tool

GRINDING OF TOOLS

The lathe tools are ground off-hand or with the help of tool grinding fixture, as shown in Fig. 8.14. A good turner has a great skill in grinding his own tool of suitable geometry. While grinding, one should take proper care to see that the tool is not over heated, for then it would lose its hardness. It requires dipping into coolant in course of grinding. In machine grinding, coolants are applied during the operation through pumps. The use of proper grinding wheels is very important. Tools are generally finished by rubbing on oil-stones for longer life.

Fig. 8.14 Tool grinding fixture

TOOLS FOR VARIOUS OPERATIONS

Turning operations may be classified mainly into two groups: (i) rough operation and (ii) finishing operation. For rough operation, the tool should be sturdy and should have the right geometry to be able to resist the cutting forces effectively. Heat generated during cutting is more in the rough operation than in the finishing operation. The objective of the finishing operation is self-explanatory. In this case the tool should have a keen cutting edge and a proper radius.

The typical operations in a lathe are plain turning, parting, boring, threading

(outside and inside) and knurling. All operations are shown in Fig. 8.15. The

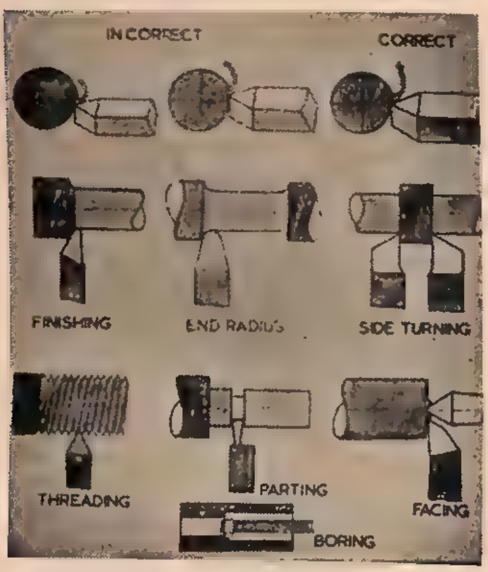


Fig. 8.15 Lathe tools—setting and operations

knurling operation is not actually a cutting operation but is rather a forming operation. A set of hardened knurls is fixed on a knurling tool holder and pressed on a machined cylindrical surface to impress its shape on the object (Fig. 8.19).

Fig. 8.16 Knurling tool

8.10 Operations on a Lathe

SETTING OF TOOLS

In all cases the cutting tool point should be set just at the centre height of the lathe (Fig. 8.13). For a small diameter object, it is set about .04 to .06 mm above the centre. This is done by an expert operator only on eye estimation, but a gauge ought to be used.

ARRANGEMENT FOR HOLDING JOBS ON CENTRES

The object is to be centred at both ends by means of a centre drill. For a small object, this operation can be done in a drill machine. For a long object, the operation is done in a lathe machine, a chuck and a steady are used to hold and rotate the object concentrically and the tailstock is used for centring (Fig. 8.17). After being centred, the object is held on the centres of the lathe and is driven by a driving plate through the dogs. It is now ready for operation.

Plain Turning

The object is held either on centres, or by a chuck or collets and is turned on its diameter. For stepped turning, special type of tools are used. Care must be taken to hold the object securely, to use the proper tool and to cut with the proper speed, feed and depth of cut.

Truing a Job

This operation is often required in a lathe or other like machine tools. Sometimes a rough object or a pre-machined cylindrical object is required to be held on a lathe chuck concentrically. In such a case the use of a four-jaw independent chuck is essential. The object is held by a chuck and is allowed to rotate very slowly preferably by hand. The eccentricity of the job can be judged roughly by eye estimation. But for accuracy, generally a piece of chalk is held by hand against the rotating object. If the object is concentric,

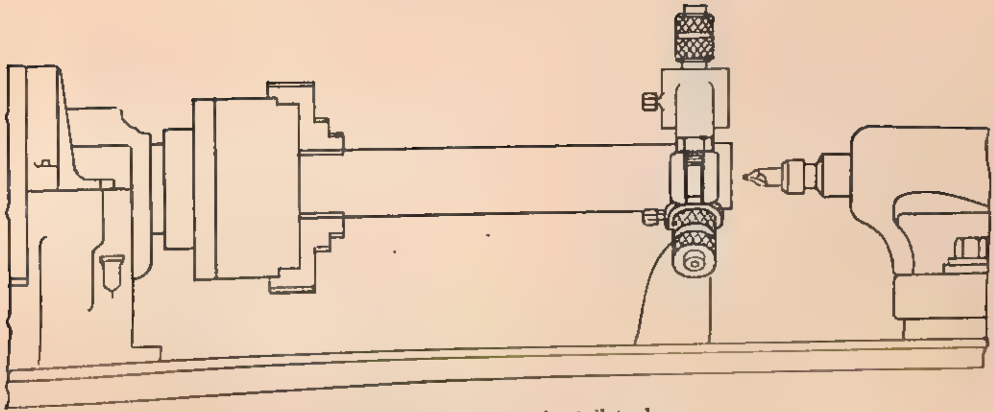


Fig. 8.17 Centring by tailstock

it will have chalk marks all round; if it is not, the chalk marking will be only at one place. This will give the operator an indication for adjusting the jaws. By trial and error, the object can be trued by shifting the jaws suitably. The scribing pin of a marking gauge or a dial indicator is more commonly used for the accurate truing of a machined surface inside or outside. For the accurate location and drilling, tool maker's buttons are commonly used (Fig. 8.18).

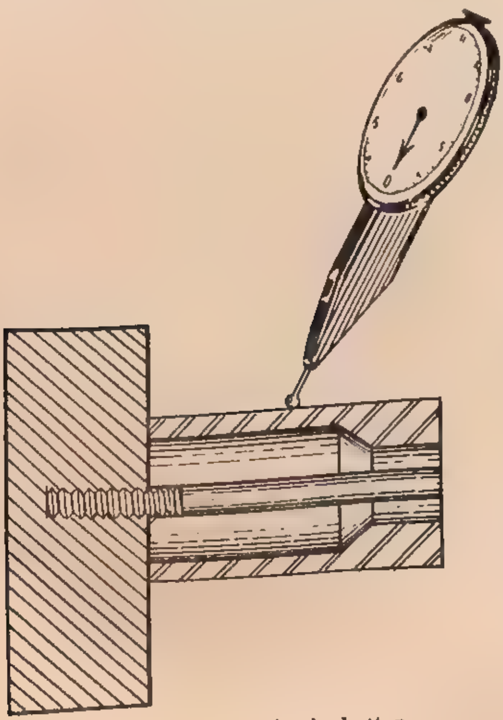


Fig. 8.18 Turning by button

Taper Turning

Taper turning is the process for producing conical surfaces both outside and inside. This is generally done on the lathe by

(a) off-setting the tailstock centre,
(b) using the compound slide,
(c) using a form tool, or
(d) using taper turning attachment.

For longer objects which are held on centres, a small degree of taper can be obtained by off-setting the tailstock centre and allowing the tool to move parallel to the axis of the machine. The taper is generally expressed in degrees or as change of diameter per unit axial length of the object. The difference between the diameters at the two ends, together with the axial length between the two ends may also express the taper. From one data the operator can easily calculate the other, as

$$\tan X = \frac{D-d}{2L}$$

where X = 1/2 angle of the taper
D = big diameter
d = small diameter
L = axial length of the job

Off-set of tailstock centre can be found out thus:

$$\text{Off-set} = \frac{D-d}{L}$$

But if x be the total length of the object between the centres and L be the axial length of the taper on which D and d are the diameters to be found, then

$$\text{Off-set} = \frac{X}{L} \cdot \frac{D-d}{L}$$

For a short taper, the compound slide is used if the taper length is within its capacity. In this case the taper is to be expressed in angles and the compound slide is swivelled to half the angle in the proper direction. Both outside and inside tapers can be cut in this way. One should be careful to swivel first and then set the tool. Still shorter tapers can be cut on the lathe by a form tool. The tool cutting edge is ground straight and cuts along the whole length of the taper. The tool is fed straight into the job. This method is commonly used in production machine tool. Any degree of taper of short length can be obtained by this method.

Long tapers in production can be cut by a single-point cutting tool on a lathe having a taper turning attachment. The cross-slide screw is disengaged from the nut and is fixed at its end on to the slide of the taper-turning attachment through a lever (Fig. 8.19). As the carriage moves along the bed, the cross-slide motion is controlled by the taper-turning attachment, so that the cutting point of this tool follows the guide of the taper-turning attachment. Only a small taper angles up to 30° can be obtained by this method.

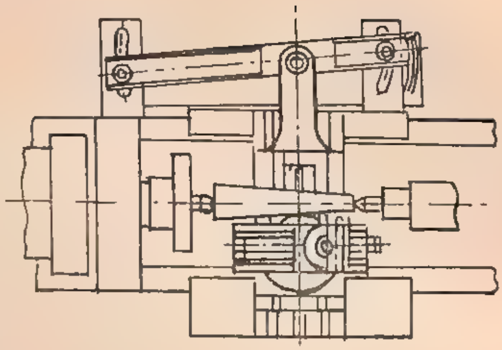


Fig. 8.19 Taper turning attachment

Drilling and Boring

Internal cylindrical surfaces, i.e., holes, can be obtained on the lathe. The operation of initiating a hole in an object is called drilling and is done by holding a drill with a chuck on the tailstock. The taper of the chuck fits through one or more sleeves to the taper socket of the tailstock end. In a lathe, drilling can be done only through the axis of the object. Boring is the operation of enlarging a hole with the help of a single-point cutting tool. A boring tool is held on the tool post and engaged on the object as in Fig. 8.15. As the carriage moves, the object is machined. The commercial drill is normally manufactured to about 50 mm diameter; so the dimension which can be obtained by drilling is limited. But boring has no limitation only if the capacity of the machine permits. So big holes are made by boring. Accurate holes of big sizes are also made by boring, whereas small accurate holes are made by reaming.

Knurling

By this process, some serrations are done on a cylindrical object. The object is held with a chuck and is rotated. The knurling tool is forced upon the surface,

and since the knurls are hardened rollers, they leave impressions on the object by displacing the surface material. The knurls may be straight or crossed, rough or fine. Knurling is done for the better gripping of the object.

Parting-off

Whenever a small object is produced from a long bar in a lathe, the finished component is to be cut off. This is done by means of a special cutting tool. The cutting off in a lathe is known as the parting-off operation and the cutting tool is known as the parting tool.

The operation seems to be simple, but in actual practice it is not. The tool is generally between 3 mm and 5 mm in width and tapered at the sides, as shown in Fig. 8.15. The cutting end is sometimes tapered so that the pimples at the end of the object may be cleaned off. The speed of parting is generally half the speed of turning. In parting-off operation, hand feed is used and the rate of feed is very small. The overhang of the tool should be minimum, otherwise the tool may vibrate and break. Cutting off by hacksaw when the machine is running is not advisable in a lathe for reasons of safety.

Screwing

Both outside and inside screwing can be done in a lathe. If the size of the inside screw is small, taps are used. But for mass production, both inside and outside threads are produced by formed tools like taps and dies. In a centre lathe, screwing is done by a single-point cutting tool.

The carriage is disengaged from feed rod and is engaged to the lead screw by means of a half nut. The lead screw is powered from the main spindle through a set of gears. This set of gears maintains a definite relation between the rotation of the spindle and the rotation of the lead screw. Consequently, the movement of carriage on which the threading tool is fixed maintains a definite relation with the rotation of the spindle. The above mentioned train of gears remains outside the headstock in a lathe machine of low cost. But in modern machine tools, the whole set of gears is incorporated in a box at the end of the lead screw and the feed rod. It is commonly known as the feed box of the machine. The feed box (quick change gear box) is controlled by one lever or a set of levers. A chart is printed on the feed box showing the lever position for particular threads to be cut. When the levers are positioned, the machine is ready for cutting threads.

The thread calculation is as follows:

$$\frac{\text{Pitch of thread to be cut}}{\text{Pitch of thread of lead screw}} = \frac{\text{Gear at the spindle end}}{\text{Gear at the lead screw end}} = \frac{\text{Driver}}{\text{Driven}}$$

In the case of two or three-started threads, the pitch is to be replaced by the lead of the screw to be cut. After setting the gears in the machine, the form of threading tool is to be ground according to the type of thread required. After grinding and checking with a pitch gauge, the tool is set on the tool post.

The tool is set against the object, as shown in Fig. 8.20, through a screw-cutting centre gauge. The height of the tool point is set exactly to the centre height of the axis of the lathe. It is now ready for work. Most centre lathes have threading dials which give the indication for engaging the half nut with the lead screw, so that the position of the tool on each cut may remain unaltered.

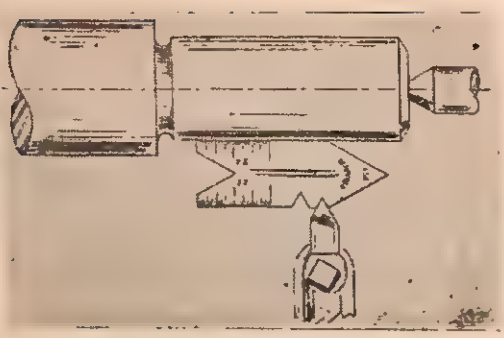


Fig. 8.20 Setting a threading tool

The material is removed slowly and with a small depth of cut, otherwise the tool may break. Gradually the proper depth of the thread is achieved and the finishing cut can be given either by the tool or by a chaser.

Similarly, inside threads can also be cut. It requires a good deal of practice to learn thread calculation and thread cutting.

Rough and Finished Machining

When an object is machined on a lathe or any other machine to definite dimensions, it should be done as quickly as possible. Heavy cut is used for quick removal of material and is followed, where necessary, by light cut for a better finish. Only 1 mm to 2 mm of material is left for finishing to size by a finishing tool on the lathe. If ground finish is required, only .1 to .3 mm material is left over and above the size and this is to be removed by grinding operation. The quality of a finishing tool lies in the sharpness of the cutting edge and the largeness of the radius. It is operated on slow feed and lubrication oil is applied.

Speed

Cutting speed is defined as the relative speed between the object and the tool when they are engaged. In the case of turning,

$$V = \frac{\pi\, d.n.}{100}$$

where, V = cutting speed (metres per minute),
d = diameter of job turned in cm., and
n = revolution per minute of the object.

Here, in practice, d is taken to be the diameter before the removal of material, but to be correct the average diameter must be taken. Increase in cutting speed helps to remove more material. But there is a limit to this. The period between two grinds indicates the tool's life. For economical operation, this life should be lengthened as much as possible. So to have a reasonably long life for the tool, the cutting speed should have some optimum value. The optimum cutting speed depends on:

(a) work material and its quality,
(b) tool material and its quality, and
(c) environment.

The recommended cutting speed is given in table 8.2 for different combinations of work material and tool material.

Table 8.2

Cutting speed meters per minute

Tool material	Work material			
	Cast iron	Mild steel	Brass	Aluminium
Carbon steel	10–12	12–18	18–24	60–120
High speed steel	18–24	30–36	60–90	120–300
Tungsten carbide	90–150	120–150	180–220	300–900

Feed

In turning operation, feed is known as the tool advance along the direction of cutting per revolution of the object.

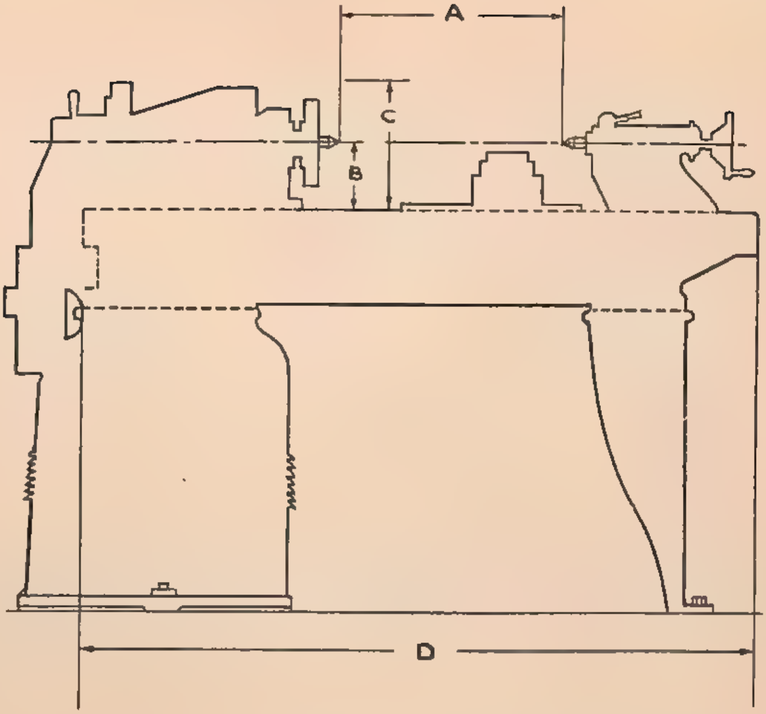


Fig. 8.21
Capacity of a lathe

A : distance between centres
B : radial swing over bed
C : diametral swing over bed
D : length of bed

Depth of Cut

In turning, depth of cut is the penetration of the tool into the object along the radial direction. Feed multiplied by the depth of cut gives the cross-section of the area which is cut to chips. This is proportional to the force of cutting.

Capacity of a Lathe

The capacity of a lathe (Fig. 8.21) is given by

(1) the distance between the headstock centre and the tail-stock centre in the extreme position, i.e., by the maximum length of the object it can accommodate,
(2) the swing or maximum diameter of the object the machine can take up on the cross-slide and also on the bed, and
(3) the horsepower of the motor of the machine tool.

30 cm x 1200 cm lathe can machine objects of the maximum dimensions of 30 cm diameter and 1200 cm length.

8.11 Shaping, Planing and Slotting Machine Tools

This group of machine tools is intended to produce primarily flat surfaces. They use one or more single-point tools for cutting operations. The relative movement between the object and the cutting tool is straight; the feeds are provided at right angles to this cutting movement and so the machined surfaces become flat. All these machine tools work on reciprocating movement either of the cutting tool or of the object. Generally, metal is cut in the forward stroke and the return stroke remains idle. Consequently, attention is given to the design of this group of machine tools so that the backward or idle stroke becomes quicker than the forward or cutting stroke

and thus the overall time for cutting is saved.

The rates of metal removal by this group of machines are rather slow in comparison to other machine tools like milling, turning machines. These are generally used for unit or batch production. But they are essential in the tool room or maintenance shop owing to their versatility and suitability in some unusual operations.

These three classes of machine tools differ according to :

(i) whether the relative motion of cutting is horizontal or vertical, and

(ii) whether the moving part is the cutting tool or the object.

Machine tools having vertical cutting motions are called slotters and those having horizontal cutting motions are called shapers and planers. Again, the machine tools in which the object remains stationary and the tool reciprocates for cutting, are called shapers and those in which the object reciprocates and the cutting tool is stationary, are known as planers. Planers are used for comparatively long and large objects and shapers are used for small objects. Planers are heavy machine tools compared to shapers.

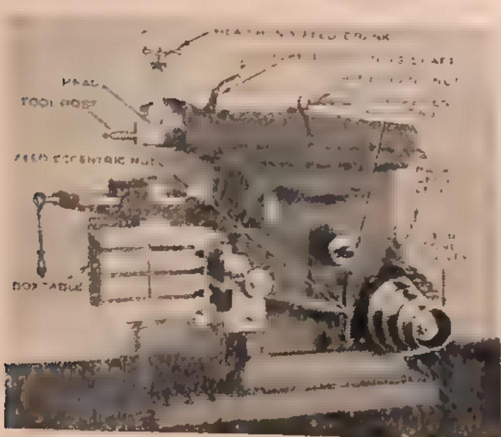


Fig. 8.22 Shaper

SHAPER

This machine tool consists of base, body, ram, tool head, and table. The names of other parts are also shown in Fig. 8.22.

The drive is given through some quick return mechanism to save working time. The mechanism may be either 'Whitworth quick return motion' or 'Crank and slotted link motion'. The cutting speed is slow and three or four speeds are obtained through cone pulley drives. But modern shapers have gear boxes for obtaining different speeds. Shapers are also driven by hydraulic power. Hydraulic shapers are generally of heavy type and give uniform cutting speed.

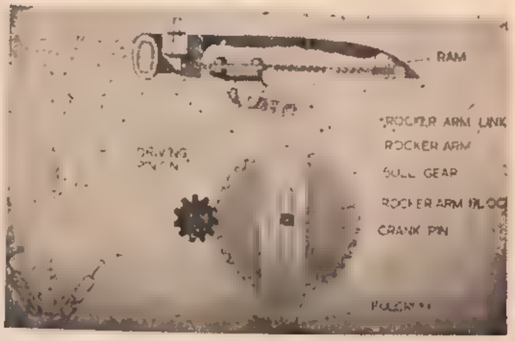


Fig. 8.23 Driving mechanism of shaping machine

Crank and Slotted Link Motion

This is used for reciprocating light machines such as shapers and slotters. The schematic diagram is shown in Fig. 8.23. Here the driving pinion drives the bull gear. The bull gear has a crank pin arrangement. The crank pin fits the hole of the rocker arm block sliding inside the slot of the rocker arm. The arm is pivoted on a fulcrum at its bottom end. The rocker arm transmits motion to ram by a link. As the bull gear rotates, the crank pin rotates too and makes the block rotate round the centre of the bull gear. Consequently, the

link moves to and fro. The magnitude of oscillation of the link depends on the distance of the centre of the crank pin from the centre of the bull gear. So the ram moves to and fro as the bull gear rotates.

The stroke of the ram of the machine is adjusted by the position of the crank pin. During the forward movement of the ram, the bull gear rotates through the major arc length and during the backward stroke, it rotates through the minor arc length. Hence it is clear that it takes more time to cover the stroke length in the forward movement and less time to cover it in the backward movement.

So,

$$\frac{\text{cutting time}}{\text{idle time}} = \frac{\text{major arc angle}}{\text{minor arc angle}} = \frac{3}{2}.$$

Approximately, cutting time=3/5 of the cycle time.

Speed and Feed

In the shaping machine, the ram does not move uniformly. It moves faster at the centre portion than at the end portions of the stroke. So in the case of reciprocating motion, average cutting speed is considered.

So the cutting speed of a shaper $=$

$$\frac{\text{stroke length}}{\text{time for forward movement}}$$

Feed is given in a fixed-head-crank-shaper by sliding the table of the machine. This is actuated by means of a screw and nut arrangement. Feeding may be done manually, but some machine tools have an automatic feed arrangement by means of a pawl and ratchet, as shown in Fig. 8.24. At the end of each backward stroke, the pawl is arranged to move one or more teeth of the ratchet wheel and thus rotate the screw for the movement of the work table.

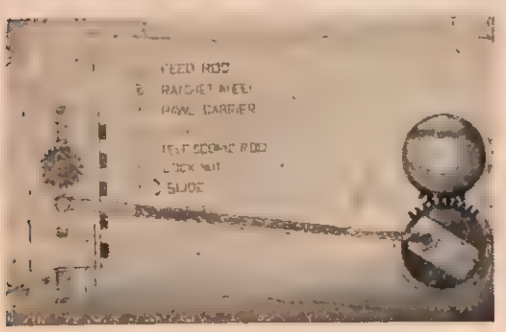


Fig. 8.24 Shaper feed mechanism

Clapper Box

In a reciprocating machine, the clapper box has been extremely useful to save the life of the cutting tools. As the ram recedes, the tool retraces its path and is likely to rub on the cut surface. The clapper box is a device for holding the tool and this is pivoted at, so that in the forward stroke it is rigid and sits on the ram head, but in the backward motion it relieves the tool from rubbing. Modern reciprocating machines have electrical arrangements to lift the clapper box (tool holder) during the idle stroke. The clapper box can be rotated at about 20° on each side. So taper machining on sides can easily be done.

Job Holding Device

In a shaper, a machine vice is commonly used to grip an object for machining. The vice is fixed by bolts on the table of the machine. Sometimes objects are also held by clamps on the top or sides of the machine table. The table of a shaper is provided with T-slots for fixing bolts and clamps.

Cutting Tools of a Shaper

The cutting tools of a shaper are generally more sturdy than those of lathes described earlier. On account of the reciprocating nature of the cutting motion, the tool has got to resist the impact of the engagement of the tool with the object.

The cutting of a reciprocating machine is intermittent and not continuous like that of a general lathe operation and thus causes impacts. The cross-sections of tools are larger than those of ordinary lathes. Of course, for a heavy duty lathe, the cross-section of turning tool is equally large. The specifications of tool angles of the shaper are considered in the same way as in a lathe. Sometimes the back rake angle is given as negative for more wedge angle of the tool to resist the impact at the start of the work. Goose-neck solid tools or tool holders are commonly used in a shaper to avoid feeding-in, specially in the case of softer work material. Observe the action of a plane solid tool and a goose-neck tool as fitted to the clapper box shaper.

Capacity of a Shaper

The capacity of a shaper is indicated by its maximum stroke length. A 30 cm shaper has the maximum stroke of 30 cm. As usual, the horsepower of the machine tool indicates its power capacity.

Operation of a Shaper

The machine tool is switched on to have the power line on. Then the machine is stopped and the crank pin position is so adjusted that the stroke length is about 12 mm greater than the job length. The job is fixed either in the vice of the machine or on the table. A properly sharpened tool is fixed in the clapper box. The ram position is so adjusted that the tool point is 3 mm ahead of the object at the foremost position and 9 mm behind the object in its rearmost position. The speed is calculated and the machine is geared accordingly. For desired feed, the pawl and ratchet system is adjusted. The tool is brought down to contact the face of this object. Then the object is taken side ways to clear the tool. Depth of cut is put and the machine is started. The feed mechanism starts working and gradually the tool and the object become engaged.

Precautions

When working on a shaper, one should never bend down and look at the cutting edge. The flying swarf may injure the eye. In this operation, the use of goggles is necessary. The lubricant must not be applied with hand or cotton waste. Cleaning of the surface must be done with a brush. One should never attempt to check the surface finish by the touch of hand while the machine is running. For the measurement of the object, the machine must be stopped.

8.12 Drills and Drilling Machines

The drilling machine is intended to produce cylindrical holes by means of a tool called drill. This is sometimes called a drill press. Here the tool rotates and the object remains stationary. The feed motion is given along the axis of rotation by the drill head. Generally, the drilling machines have vertical spindles. But horizontal drilling machines are also available. This is a very common type of machine tool used in job work and quantity production.

The drilling operation can also be done on a lathe as mentioned earlier.

8.13 Types of Drilling Machines

Common types of drilling machines can be classified as:

(i) Super sensitive drill press,
(ii) Sensitive drill press,
(iii) General purpose drill machine,
  (a) upright drill,
  (b) gang drill,
  (c) multiple spindle, and
(iv) Radial drill.

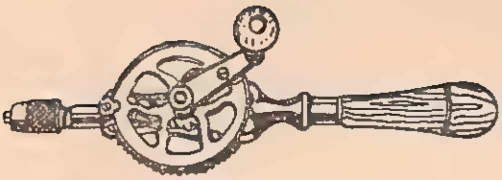


Fig. 8.25 Hand drill

Besides these, hand drills, portable electric drills and pneumatic drills are also very common. A hand drill (Fig. 8.25) is operated by rotating the crank with one hand and pressing the drill head with the other. This is commonly used in drilling wood and plastics. The portable electric drill is rotated by means of an electric motor, but the cutting pressure is applied by hand. The pneumatic drills are rotated by air motor and the cutting pressure is given manually. These two are very much used in fitting and erection work, where it becomes necessary to drill a frame, or a body on the spot (Fig. 8.26).

Fig. 8.26 Portable electric drill

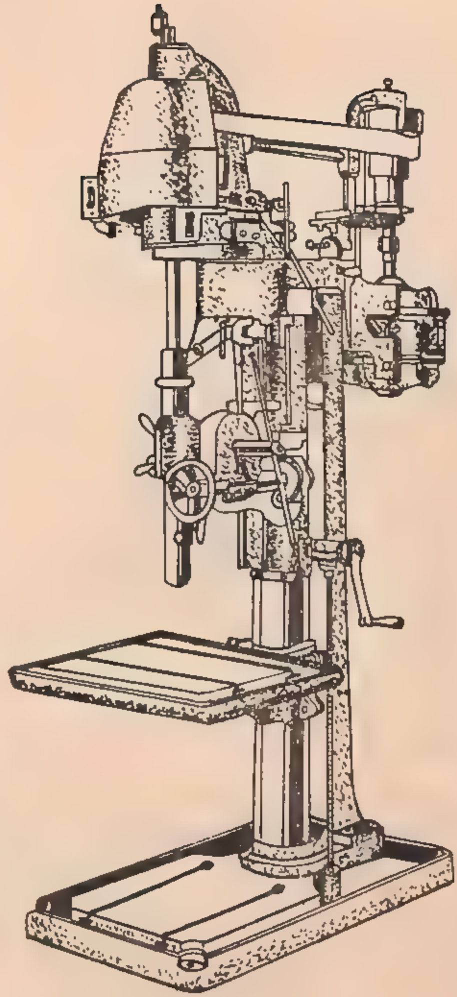


Fig. 8.27 Bench drill press

SUPER SENSITIVE AND SENSITIVE DRILL PRESSES

Both the above classes of drill presses are operated by hand feed. They are of smaller capacity and are meant for drilling fine holes in precision jobs. They are bench type and simple in construction (Fig. 8.27). The drives are taken through belts from the main motor by means of stepped pulleys. Three or four steps are generally available. To increase the steps and the range of speed, sometimes two or three speed motors are used. Gear drive is generally avoided in these to reduce vibration and to make them simpler in construction. The feed is given by hand and depends on the feel of the operator, who has got to be skilled. The other aspects of construction of the machine are similar to those of any other drill press.

GENERAL PURPOSE DRILL MACHINES

Upright Drill

The upright drill press is a high capacity machine and is generally used for heavier

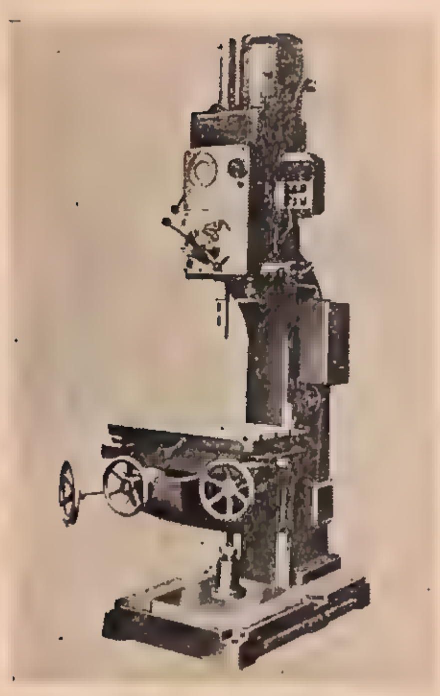


Fig. 8.28 Upright drill press

jobs and for making larger holes. This machine has often a geared headstock for different steps of speed and an automatic feed box. Belt-driven high powered drill presses are also available. The feed can be given manually. There is an automatic feed arrangement. The machine (Fig. 8.28) consists of base, pillars, table and drill head. The base is a casting machined at both faces and has slots for fixing objects. It holds the column of the machine.

COLUMN. The columns may be round bars or pipes fitted to the base or may be of cast iron integrally cast with the base. The column of the former type serves as the guide for the table of the drill press. The cast column has suitably machined guides for the sliding of the table. To increase the rigidity of the table, a screw and nut support is given at the bottom end.

TABLE. The table of the machine is a casting machined on the top face. It has a few slots to be used for clamping objects. The table of a round column machine can swing round the column and rotate round its own axis. But a cast column machine has no rotating motion. In both types, the table can slide up and down to accommodate shorter or longer objects. For smaller machines, the head can also move up and down and rotate round a circular column.

DRILL HEAD. The head of the machine tool is fixed on the top end of the column. The head consists of a geared headstock and a quill through which the spindle of the drill rotates. The feed mechanism is fixed on the quill and when engaged, it gives up and down feed motions to the spindle of the drill. The scheme is shown in Fig 8.29. The power motor is arranged to drive the drill and also to give the feed motion. The power motor is generally fixed on the top of the column and is either directly coupled to the gear shaft or by pulley and belt system. Both types of the machine are available. The column is carefully designed so that it may not deflect owing to the eccentric loading of the drill head on the top end of the column. Generally, motor and pulley are placed on the opposite sides of the column of the drill head to balance to a certain extent, as shown in Fig. 8.27. The nose of the spindle of a drill has standard taper to accommodate taper shank drill or tapered sleeves or chucks. The slot across is kept to allow a drift to open the tools or chucks.

Gang Drill

Three or four drill heads and columns are put together or fixed on a common long table. These are used for production job when drilling jigs are used and holes of different sizes are required to be made.

Multiple Spindle Drill Press

This machine has one column, but the drilling head encases a number of spindles rotated from a common drive by means of universal joints. The spindles can be positioned relative to one another as required. It is extensively used for drilling a number of holes at a time on a mass scale.

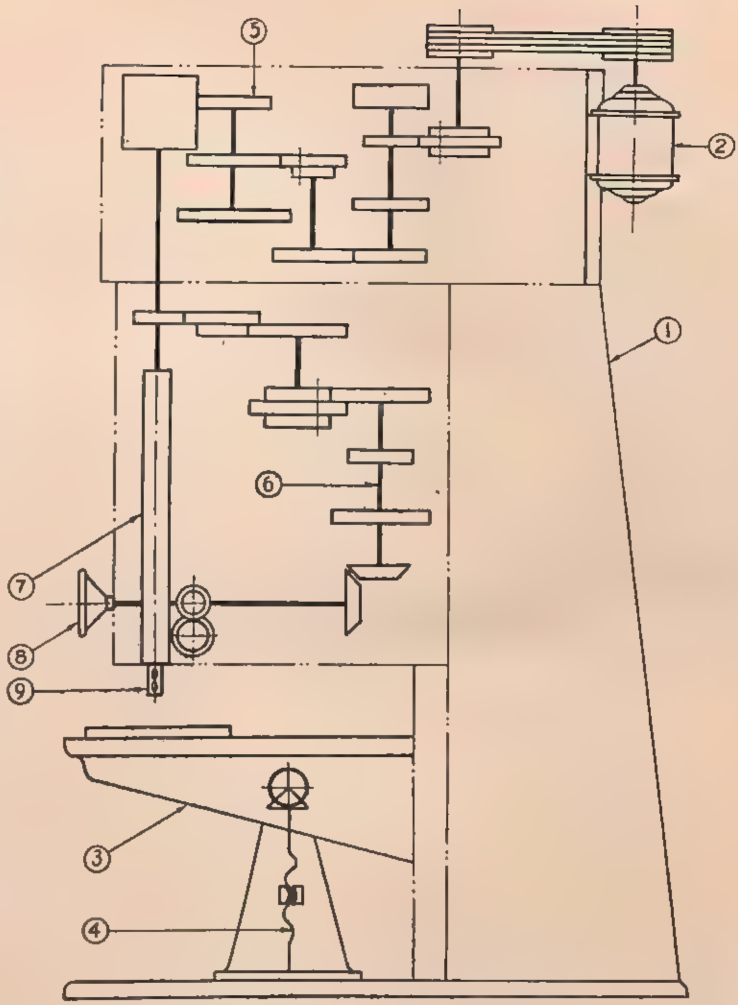


Fig. 8.29 Kinamatic scheme of drill machine
1. Column 2. Electric motor 3. Table 4. Table lifting screw 5. Geared head stock 6. Feed mechanism 7. Quill 8. Handle 9. Spindle

RADIAL DRILL

This machine has been designed to make a drill press more universal and to suit varieties of larger objects. When an object is quite heavy and difficult to handle, a mobile drill head is used to make a number of holes at a time. The drill head is made mobile by adding a horizontal radial arm on which the drill head can slide and be positioned, as required.

The arm itself can also swing round the column. So the drill head has quite a big area of work so that larger jobs can be handled easily (Fig. 8.30).

Capacity of a Drill Press

In general, the capacity of any drill press except the radial drill is denoted by the diameter of the biggest hole it can bore. This, of course, depends on the power available and the machanical parts. A 1/2″ drill press means a drill machine which can make 1/2″ drill in steel. Besides, the size of a drill press is also mentioned as twice the distance from the column side to the centre of the drill, i.e., the diameter of the object it can accommodate when its centre is to be drilled. For radial drill, the capacity is given as the distance from the side of the column to the farthest position of the drill head on the radial arm.

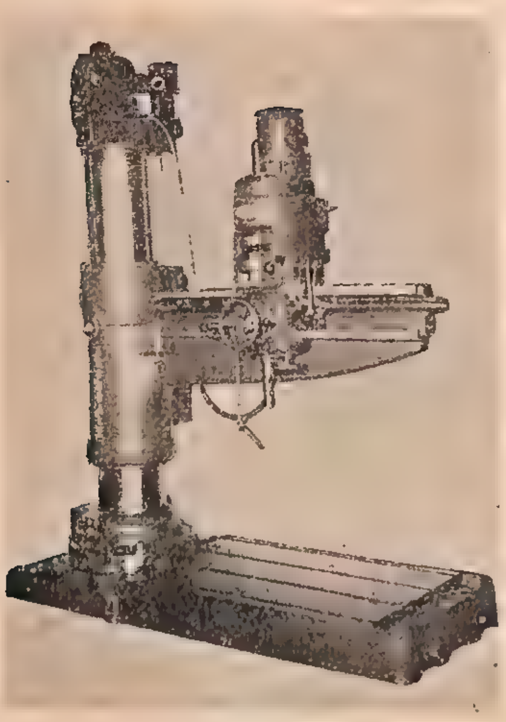


Fig. 8.30 Radial drill

SPEED AND FEED

It must be noted that the two cutting edges of a drill extend from near the axis of the tool to the circumference. When a drill rotates, the linear velocities of the different points of the cutting edge are not the same. It is the usual practice to denote the cutting speed of a drill as the rate of movement of a cutting point on the circumference of the drill. It is the maximum speed with which the extreme edge of a drill cuts. This is expressed as linear velocity per minute.

$$\text{So,} \quad V = \frac{\pi \, D.N.}{100}$$

where V = cutting speed of a drill in metre per minute,

D = diameter of the drill in centimetre, and

N = number of revolutions of the drill per minute.

As in turning operation, the cutting speed of a drill depends on the work material, the tool material, the coolant and the finish required

As in turning, the feed for a drilling operation is the advance of the tool inside the object per revolution of the spindle. It is to be noted that if a drill has two cutting edges, the actual cut by each edge is equal to half the feed.

8.14 Drilling Operation

The first operation in drilling is to mark the exact positions on an object where holes are to be made. Then the positions are to be punched lightly, first with a centre punch. If any punching goes wrong, the centre punch is held slantingly and by light hitting the centre is brought to the correct position. When it is correct, a deep punch mark is made. For accurate drilling, a few circles are drawn with different radii round this punch as centre.

When drilling is started, the deep punch mark gives it the lead. This can easily be checked by comparing the circular dimples with the circles drawn. If it is not correct, the centre has to be shifted again with a centre punch and the drill is tried. After this correction, drilling is started once again. For correct lead to a drill, countersinking may be done with a centre drill (Fig. 8.31). This is extensively used in accurate drilling operation either in a

COMBINATION DRILL AND COUNTERSINK

Fig. 8.31

drill press or in a lathe. Accurate drilling on a mass scale is done by guiding the tool in a drilling jig, which operation is beyond the scope of this book. However, before drilling is started, suitable speed and feed are to be selected and the drill press is to be geared for them. The object should be fixed on the table of the drill press by means of a machine vice or by clamps. Long objects are gripped by hand for drilling but stops are provided in the slots to resist the rotation of the object with the drill.

Operations that are generally performed in a drill press, besides drilling holes, are reaming, countersinking, counter boring, spot facing, and tapping.

REAMING is the operation of finishing and sizing a hole by means of a reamer. This can be done on a drill press by rotating the reamer on the spindle of the machine like a drill and can be fed into the hole of the object. For the lead, the reamer is sometimes tapered at the end. The flutes of a reamer may be straight or helical (Fig. 8.32). The speed for reaming is about one third of the speed of drilling but the feed is three times faster. Since reaming is a finishing operation, the object should be lubricated as often as necessary.

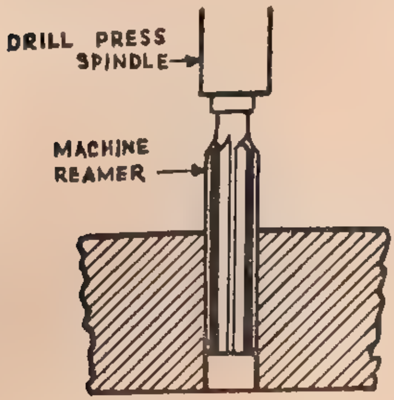


Fig. 8.32

COUNTER BORING is the operation of enlarging to a depth a pre-drilled hole. The enlarged hole portions must be concentric with previously drilled hole and the latter is used as a pilot guide. The counter boring is done for accommodating the head of a socketed head screw below the level of the surface. The tool used for this operation is called counter bore (Fig. 8.33). It has a number of cutting edges both at the end and on the periphery. The speed for counter boring is slower than drilling.

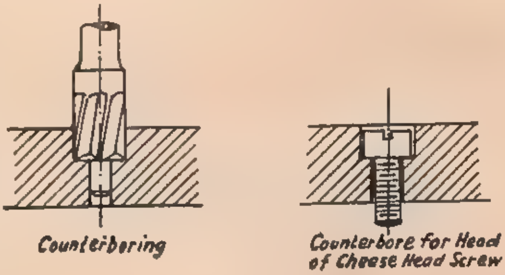


Fig. 8.33

COUNTER SINKING is an operation that does the beveling of the end of a pre-drilled hole to accommodate a counter sink screw. A counter sink cutter (Fig. 8.34) has a number of tapered cutting edges forming a cone of 82°. It should be run at a slow speed.

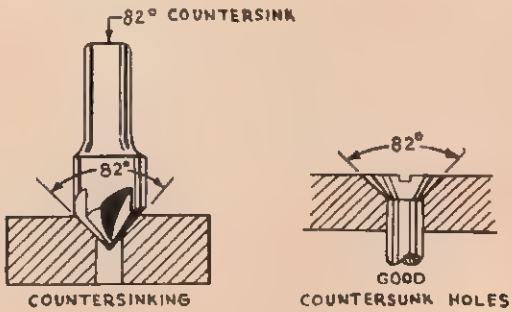


Fig. 8.34

SPOT FACING is just to machine and clean some area on the surface round the axis of a hole, so that it provides good flat bearing surface for a bolt head or a washer to seat. The tool is similar to the counter bore, except that it has cutting teeth at its end (Fig. 3.35).

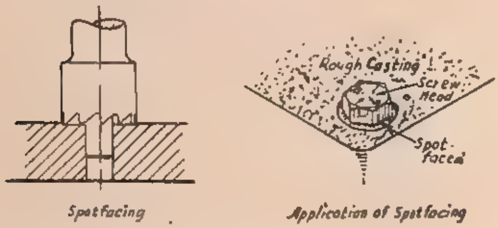


Fig. 8.35

TAPPING can also be done in a drill press. The tap is held by a drill chuck on the spindle and is slowly rotated and fed into the hole to be tapped and by the pressure of hand (Fig. 8.36). For faster production, a tapping attachment is used in a drill press. White lead or lubricating oil is used as coolant during this operation.

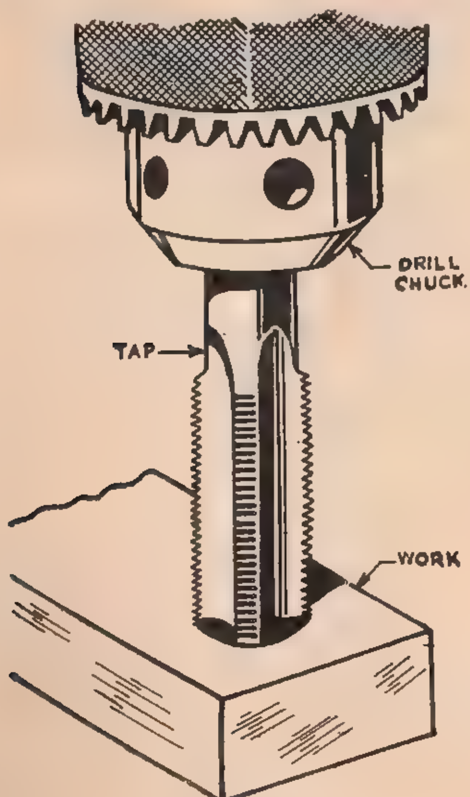


Fig. 8.36

8.15 Drills

There are three types of drills : (i) Flat drill, (ii) Straight fluted drill, and (iii) Twist drill.

A flat drill is usually made in shops at low cost from high carbon steel. It is forged, hardened and tempered, and then ground for use. It is only used for some very special jobs. It is not as efficient as a twist drill. The straight fluted drill (Fig. 8.37) is used for soft metals and sometimes for thin sheets.

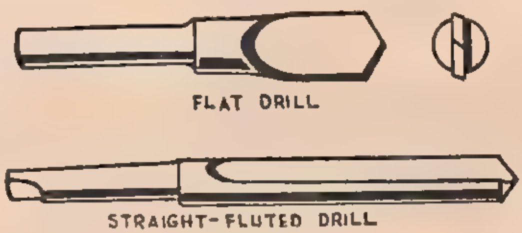


Fig. 8.37

The most generally used drills are the twist drills (Fig. 8.38). These can be used for all types of jobs. The different parts of a two-fluted twist drill are shown in Fig. 8.38.

SHANK. The back portion which is used for holding the drill is known as the shank. The shank may be straight or tapered. The tapered shank of a twist drill is machined flat at the end to fit the slot of a sleeve or the drill spindle. This flat end is called the tang of the drill. The tang is made for easy removal of the drill from the socket by means of a metal drift (Fig. 8.39).

BODY. The cutting portion of the drill is

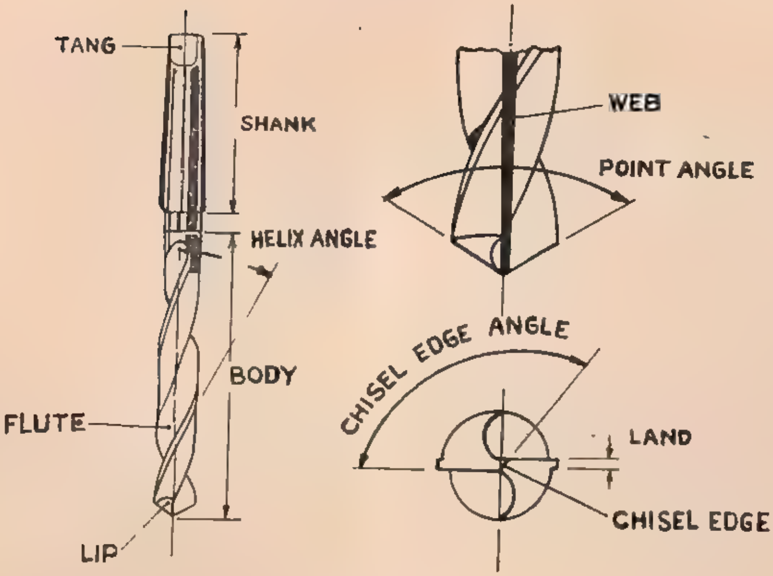


Fig. 8.38 Twist drill

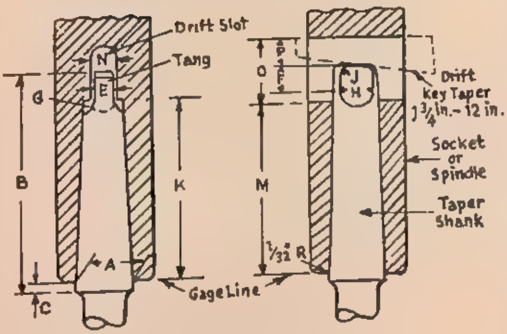


Fig. 8.39 Opening drill by drift

the body. The body has helical flutes along the axis. The body is relieved a little, otherwise it rubs against the hole made by the cutting edges. The relief is done both along the axis for a few thousands of an inch and also along the circumference keeping a narrow margin called land.

WEB. It is the back bone of a drill. It is the centre metal part and runs along the axis. It gets thicker as it approaches the shank, making the drill strong. The web end is a cone shaped cutting end known as the point of the drill.

LIPS. These are the cutting edges of a drill and the lips approach the web to form the chisel edge. The heel is the part behind a cutting edge.

GEOMETRY OF THE DRILL

The point angle of the drill is the angle between the lips (Fig. 8.38). This is usually 118°. The lips must be of equal length. If the lips are unequal the hole produced becomes bigger in size. If the angles of the lips are unequal, one lip cuts but the other does not. The angle between the chisel edge and the lips as seen on plan (Fig. 8.38) is kept between 120° and 135°.

The helical flutes form the rake angle of the cutting lip. The helix angle of an all-purpose twist drill is usually made 20°. The chips curl and pass easily through

flutes and come out of the hole. The flutes give the coolant easy passage to reach the cutting edges.

The clearance of the lips is generally 12° to 15°. If it is more than 18°, the cutting edges become weak and if less than 12°, the effective clearance angle becomes inadequate for cutting.

GRINDING OF DRILLS

Correct off-hand grinding of a drill (Fig. 8.40) is an art and can be acquired only after a long practice. Drill grinding gadgets are available for accurate and easy grinding. Drill angle gauges are used for checking lip angles, length of lips and clearance angles (Fig. 8.41).

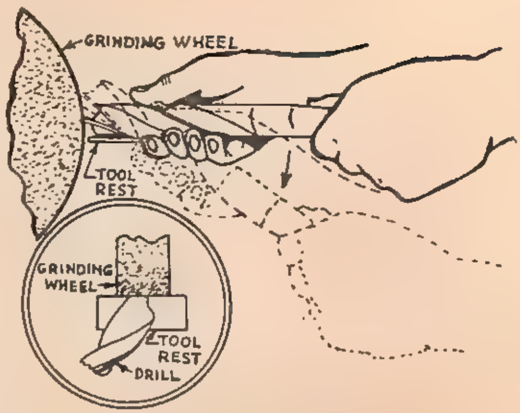
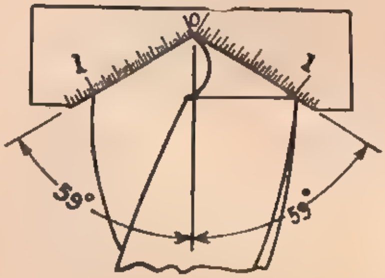
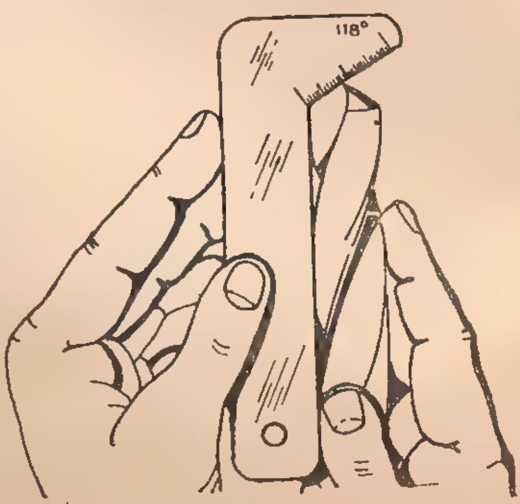


Fig. 8.40

Fig. 8.41





DRILL SIZES

Drills are commercially available in various sizes. The inch size drills vary from 1/64″ to 4″ in steps of 1/64″. The metric size drills are now made according to the Indian standards. Also number size (1—80) and letter size drills (A—Z) are used in shops. Drill sizes can be measured with an outside micrometer. But for ready use drill plate gauges are employed in shops. Drill sizes are generally punched on the shanks.

SPECIFICATION OF TWIST DRILLS

Twist drills are specified by their diameters, shapes of the shank and material of the tool. The specifications of a twist drill are : 20 mm diameter taper shank, high speed twist drill.

8.16 Holding Devices of Drill

DRILL CHUCKS

A drill chuck (Fig. 8.42-8.43) is used for gripping straight shank drills and it

has standard tapered ends to fit the taper nose of a drill spindle. The chuck has three jaws to grip a drill and it works on the principle of taper to open or close the jaws. The outer body is rotated by means of a bevel key. The size of a drill chuck is denoted by the maximum diameter of the drill it can grip. The maximum capacity is 1/2″. Large size drills have taper shanks.

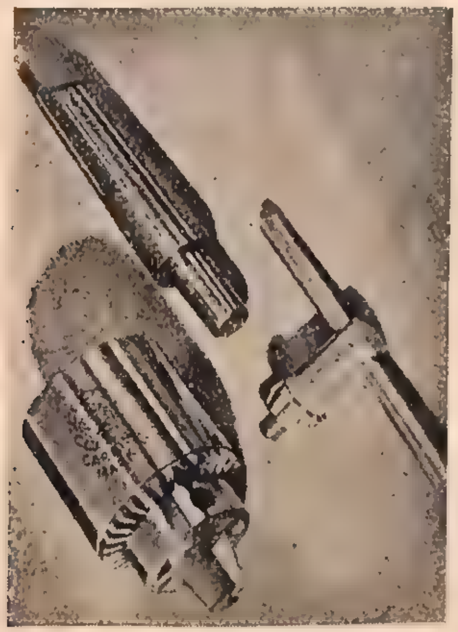


Fig. 8.42 Drill chuck

DRILL SLEEVES AND SOCKETS

A drill sleeve has both inside and outside standard tapers. They are specified as Morse taper numbers, say, 2 to 3, or 1 to 2, or 1 to 3. In some cases more than one sleeves may be necessary to fit a taper-shank drill to a drill spindle. Drill sockets may have smaller outer taper and bigger inner taper. This type of sockets is used when the drill has a higher number of taper shank and the drill machine a lower number of taper in the spindle nose. Besides Morse tapers, other standards of

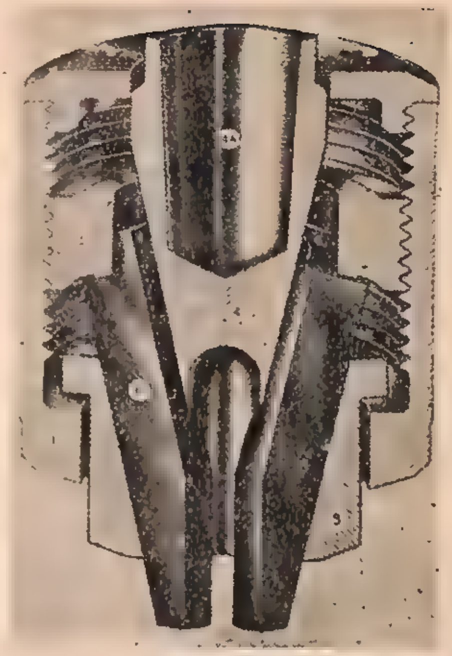


Fig. 8.43

tapers are used in different countries.

PRECAUTIONS

When using a drill press, one should never bend down and try to look at the drill, for chips may fly out and injure the eyes and the hair may get caught in the drill spindle. The same may happen if loose sleeves and garments are put on. One must not try to remove the chips when they get entangled as they are very hot and may burn the fingers. One should never try to drill by holding an object with hands only. Very often, accidents leading to injury to the hand occur as a result of the sudden rotation of the object along with the drill.

8.17 Lubricants and Cutting Fluids

FRICTION

When one body slides over another, there is always some contact-resisting

force which opposes the motion. This force of resistance is known as friction.

Result of Friction

In machine tools or other equipment, wherever there is a sliding motion (rolling motion as well), the force of friction comes into play. This frictional force generates heat and causes considerable wear as a result of constant rubbing. Heat so generated wears out the tool considerably. This is always detrimental to the long life of sliders.

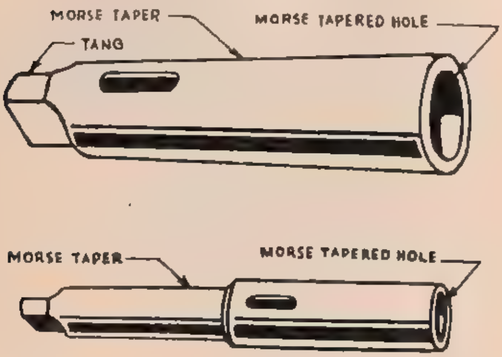


Fig. 8.44

Remedy

An engineer should always make provision in his design for the application of lubricants for the long life of sliders.

LUBRICANTS

These are substances applied between the surfaces of contact of two sliders for the purpose of minimising friction between them. They form thin layers between the sliding surface and prevent contact. Thus the wear due to abrasion is reduced. Heat generated is easily conducted from the surfaces of contact with the help of (circulatory) flowing lubricants in some cases. Lubricants are generally liquids and semi-solids. Gaseous and solid lubricants are also used in some cases.

Oils and greases are common lubricants used in workshops for lubricating bearings, slides, gears, etc., in machine tools. These are mineral oils and fatty oils obtained from animal and vegetable sources. Manufacturers produce lubricating oils under their trade names. They are prepared from one or more of the above oils with some additives, such as sulphur and chlorine compounds to improve their quality. The properties desired in lubricating oils are low viscosity, high specific heat, high thermal conductivity, high flash point and oiliness (high degree of adhesion to metals). They should be non-corrosive in nature.

Cutting Fluids

Cutting fluids are also lubricants and are sometimes called coolants. They are applied to the work and the tool to help the cutting operation. The advantages of the use of cutting fluids are :

(a) long tool life;
(b) high rate of cutting;
(c) low power consumption;
(d) low cutting temperature;
(e) better surface finish; and
(f) easy chip formation.

Mineral Oils

These are obtained from oil deposits inside the earth. The chief source is petroleum or crude oil. Huge deposits of petroleum have been found in the U.S.A., Persia, Russia, Arabia, Iraq, Mexico and Indonesia. Comparatively small deposits of oil also occur in Burma, India, Japan, Rumania and other countries. From

petroleum the following things are obtained :

1. Gasolene —It is highly explosive and inflamable. It is used as fuel for driving aircraft, automobiles, etc., and is sometimes used for cleaning.
2. Kerosene —It is used for lighting, in jet engines, for cleaning and sometimes as a lubricant.
3. Benzene —It is highly explosive and is used for cleaning greasy parts.
4. Naphtha —same as 3.
5. Lubricating oil —It is used for lubrication.

Animal Oils

Animal oils that are obtained from animal fat are:

Sperm oil—It is obtained from the head of whales. It is thinner than lard oil and is used for oiling precision machines.

Lard oil—It is obtained from the fat of hogs and is the best cutting fluid.

Fish oils—These are obtained from fish, and so have a very strong fishy odour. These are thick oils and are used in some cutting operations.

Vegetable Oils

These are obtained specially from seeds of plants and vegetables. Castor oil is used in medicine and in some special cases for lubrication. Linseed oil is used in painting. Turpentine is used for cleaning and painting and sometimes as a cutting fluid.

Greases

These are animal fats obtained from cattle. These are used for lubrication.

Solid Lubricants

Graphite powder is sometimes used as a lubricant between sliding surfaces. White lead thinned with lubricating oil is also used as a good lubricant in certain cases.

8.18 Application of Lubricants

Machine tool bearings are always provided with caps and holes through which bearings can be either greased or oiled. Sometimes lubricants are supplied automatically to the sliding surfaces simultaneously with the rotation or sliding of the members. Lubrication is also done manually with the help of a grease gun or oil can. A good operator is very careful to see that every position of his machine tool is properly lubricated. Thus he ensures the long life of his machine tool.

To obtain the above mentioned qualities in a machining operation, a cutting fluid should have :

(a) high capacity for heat absorption;
(b) better lubricating properties;
(c) stability and odourlessness;
(d) non-corrosive nature;
(e) sufficient fluidity; and
(f) low cost.

The common cutting fluids used in machining operations are :

1. Plain water or water mixed with soft soap or soda-ash. Plain water rusts the object or the tool and that is why an alkali salt is added.

2. Straight mineral or fatty oil and sometimes mixed oils are used as lubricants. These are very efficient but expensive.

3. Cutting compounds or soluble oils are the most common cutting fluids used in machine shops. These generally consist of mineral oils kept in suspension in an emulsifier such as sulphonated oil or soap.

Glycol or alcohol is also added to the soluble oils. When a soluble oil or paste is mixed with water, it looks like milk. Small globules of oil remain in suspension in the water. This lubricant is of low cost and is used practically for all cutting operations with oil water ratio as 1 to 20.

4. Cast iron is machined dry, without the application of any lubricant.

Cutting fluids are generally pumped through pipes to the area of cutting. Now-a-days, almost all machine tools are provided with coolant pumps operated by a small motor. The fluid flows in a re-circulatory system. The coolant is collected in a tank, and then passed through a strainer. It is pumped again through the delivery pipe.

CUTTING FLUIDS USED FOR COMMON METALS

Metals	*Cutting fluids in general cases*	*Cutting fluids in special cases*
Aluminium	Kerosene or Kerosene mixed with emulsified oil; turpentine.	
Brass	Dry, or light mineral oil with 10% fatty oil	Lard oil for threading
Bronze	Dry or soluble oil	
Copper	Dry or kerosene	Lard oil for threading
Babbit metal	Dry or lard oil	
Monel metal	Soluble oil	
Cast Iron	Dry	Lard oil or white lead may be used for tapping
Steel		
Bright bar	Straight or mixed oil	
Black bar	Soluble oils	
Casting	Soluble oil	Mixed oils may be used for threading

WORDS TO KNOW

Machine Tool, Transmission, Lathe, Bed, Head-stock, Tail-stock, Lead-screw, Feed Bar, Saddle, Apron, Cross-slide, Hand-slide, Tool Post, Chuck, Knurling, Change Gear, Shaper, Slotting Machine, Planer, Cutting Speed, Feed, Depth of Cut, Clapper Box, Drill, Reamer, Counter-sink, Counter-bore, Spot Face, Lubricating Oil, Cutting Fluids.

QUESTIONS

What is a Machine tool?
What is the function of a machine tool?
How do you classify the different types of Machine tools?

What is a Machine shop?
What are the types of transmission used in running machine tools in machine shop?

What is the function of a lathe?
How are lathes classified?
Name the main parts of a lathe machine and state their functions.
Sketch the section of a lathe bed indicating the guides.
What is the purpose of back gear of a lathe and how is it operated?
Sketch the transmission scheme of a lathe machine.
What is the difference between a cone-pulley driven lathe and an all-geared head-stock lathe?

What is the function of a tool post?
How does a lathe carriage move?
How do a lead screw and feed rod help in the operation of a lathe?
What are the different types of holding arrangements used in a lathe?
What is the difference between an independent chuck and a self-centring chuck?
How many are the types of steadies used in a lathe and where are they used?

Draw the sketch of a lathe tool showing the important angles.
How do you sharpen a lathe tool?
Distinguish between tools for rough and finish turnings.

Name the different operations that can be done on a lathe. Illustrate by sketches.
How do you set a single-point tool on a lathe?
What do you mean by the truing of a job on a lathe and how is it done?
What are the different methods of turning taper in a lathe? Give examples.
How will you find the offset of tailstock for cutting the given taper on a job?

What is knurling?
Why knurling is used on a job?
How knurling is done on a lathe?

Explain in detail how you will cut screw threads on a lathe.
How do you calculate change-gears and set threading tools for cutting screws on a lathe?

What do you mean by cutting speed, feed and depth of cut in a turning operation?

Explain with sketches how you will turn (a) a pin, (b) a hexagon head bolt and (c) a stud on a lathe machine.
What is meant by the capacity of a lathe?

What are the general characteristics of a shaping, slotting and planning machine?
What is meant by quick return motion?
What is the type of quick return motion used in a shaper?
What is the cutting speed of a shaping operation?
Name the main parts of a shaping machine and write their functions.
What is the function of a clapper box?
How are jobs held in a shaping machine?
Sketch the cutting tools of a shaper?
How do you specify the capacity of a shaper?
What are the precautions you will take in a shaping operation?

What are drilling machines and how do you classify them?
What are the main parts of a pillar drill? State their functions.
How do you express the capacity of a drill machine?
What is meant by speed, and feed in a drilling operation.
What is a centre drill and why is it used?
Explain the following operations with sketches:
(a) reaming,
(b) counter-sinking,
(c) counter-boring, and
(d) spot facing.

Sketch a twist drill and name its different parts.
How do you grind and check a twist drill?

How are drills held in a machine?
Write the uses of drill chuck, sleeve, and socket.

What is the function of a lubricating oil?
State the different liquids used for coollants.
Which are the cutting fluids used in machining M.S., aluminium, and copper.

CHAPTER 9

Finishing Methods

9.1 Corrosion

Corrosion is the destruction of metals and alloys by chemical or electro-chemical action with their environments. Most common metals and alloys are corroded by the atmosphere, water, etc., to form compounds. The compounds are mostly oxides, hydroxides, hydrated oxides, carborates, sulfides, etc. Most of these are insoluble and remain separated from the parent metals and alloys and are commonly known as *rust*.

Corrosion is essentially the reverse process by which metal is extracted from ores. In extraction energy is supplied, but in corrosion energy is liberated. Corrosion is mainly a surface phenomenon.

CORROSION AND EROSION

Erosion is a phenomenon very closely related to corrosion. It is the wearing away of materials by mechanical agencies. and not by chemical or electro-chemical action as in the case of corrosion.

WHY IS THE STUDY OF CORROSION IMPORTANT ?

According to an estimate, metals and alloys worth about 600 crores of rupees are wasted by corrosion annually in the world. To prevent such a great waste, engineers and research workers have to find ways and means for the prevention of corrosion.

HOW CAN CORROSION BE FOUGHT ?

1. Metals and alloys should be treated and developed in a way that prevents harmful exposure to the environment.
2. Environments should be controlled and adjusted so that common materials are less liable to corrosion.
3. Suitable protective coatings may be used on the surfaces of metals and alloys. The protective coats are generally metallic, organic or inorganic substances.

WHAT HAPPENS IN CORROSION ?

Metals generally have free valence electrons which account for their metallic bond and electrical conduction. These loosely bound electrons in metals are easily removed and form stable compounds by chemical action with environments. Only the noble or most passive metals like platinum and gold are found in free state in nature. All other metals in natural conditions form compounds with oxygen, sulphur and chlorine, etc., and are found as ores. The natural tendency of a refined metal is always to be transformed to the condition of the ore in contact with atmosphere. Sometimes the product of

corrosion is loosely bound with the parent metal, such as rust on iron, and allows the progress of corrosion further. Metals like aluminium, brass, copper, zinc, tin, lead, chromium, stainless steel, etc., belong to the second type. The process of corrosion is exactly like the reactions in a galvanic cell. Some part of the exposed metal becomes anodic to the remaining part and in the presence of a suitable liquid environment (water) the galvanic reaction starts (Fig. 9.1). Water and oxygen help the rate of corrosion. In the case of iron, corrosive action leads to the product Fe_3O_4. This takes place even in oxygen-free water. The strained areas of metals, impurities in metals, areas of low oxygen concentration and areas where the protective film is broken, become anodic to the rest of the metal. Localized

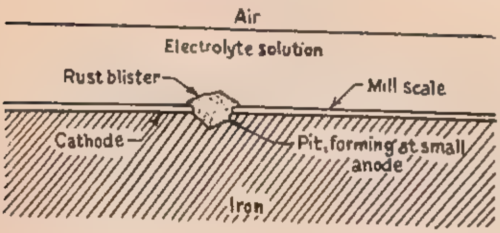


Fig. 9.1 Galvanic action

corrosion is known as pitting (Fig. 9.2). Failures in serviceability are generally due to localised corrosion rather than to moderate corrosion spread over the whole area. Particular attention should be given to stop pitting in a metal.

9.2 Protection against Corrosion

This is generally done by applying a coating of another metal or alloy which is more resistant to corrosion. This coating should be inexpensive. Inorganic (non-metallic) and organic coatings are com-

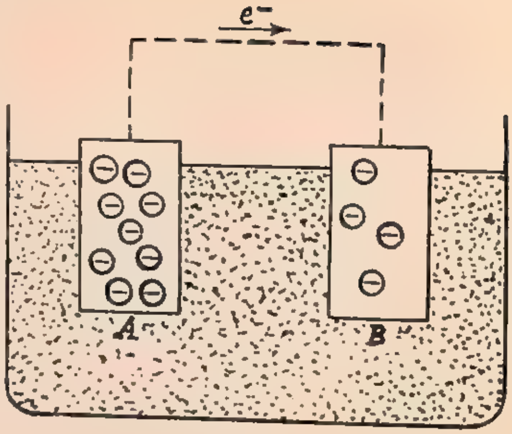


Fig. 9.2 Pitting

monly used. Coatings have also very high decorative value.

9.3 Coatings

One of the processes of great antiquity is to cover cheaper base metals with thin sheets of gold or silver. This was done in the past by hammering sheets of noble metals on heated base metals. Tinning of iron dates from 1600 A.D. and galvanizing from 1740. Fusion of silver sheets on brass and copper started in 1743. Electric deposition of metal was devised in1840. Now-a-days, various methods are used for metallic coating in industry.

METAL FINISHING

Metal surfaces may be machined or unmachined. Machined surfaces are finished by scraping, frosting, flaking, grinding and plating. Unmachined surfaces are generally galvanized, tin plated, electroplated, or painted.

CLEANING OF METAL SURFACE FOR COATING

Metal surfaces to be coated have to be

cleaned properly, otherwise coatings do not adhere and they peel off. Cleaning is usually done in three steps :

1. Removal of dirt and degreasing,
2. Removal of rust,
3. Etching or abrasing treatment.

The most common method of cleaning is by dipping the article in an alkaline cleaner like hot caustic soda solution. Other alkaline cleaners are sodium phosphate, sodium silicate, borax, alone or in combination with other chemicals. The use of Trychloroethylene as degreasing agent is very common. After the articles have been pickled in cleaning vats they are always removed with tongs, pliers or nets. If they are held with fingers they get contaminated with grease.

Rust scales or other corrosion products are removed by grinding, wire brushing, shot or sand blasting or by acid pickling. To remove mill scales, iron and steel are pickled in 4 to 5% sulphuric acid solution at 65° to 75° C. To decrease acid action, inhibitors are used. Copper is pickled in sulphuric acid solution, whereas brass and bronze are pickled in a mixture of sulphuric acid and hydrochloric acid containing a small amount of nitric acid. In order to be painted, steel is pickled in phospheric acid solution or dipped in phospheric acid solution after being pickled in sulphuric acid solution.

After being pickled the surfaces should be made rough for the better adhesion of coats. This is done by etching or abrasion.

9.4 Metal Coating Processes

HOT DIPPING

In this process, the clean article is dipped in a hot bath of molten metal or alloy for sufficient time, so that a film of coating adheres to the surface. This method is widely used for coating of metals and alloys of low melting point such as zinc, tin, lead and other metals. This is a very inexpensive method.

METAL SPRAYING

In this process, the metal to be coated is melted, atomised and sprayed on the surface of the article. This method is particularly advantageous when the article is too large to be dipped into a bath of average size. This method is used for coating of aluminium, brass, copper, nickel, tin and similar other metals.

METAL CLADDING

This process means clothing or covering a base metal with a noble metal. One method is casting a composite ingot so that the base metal is covered with a noble metal. Then the ingot is rolled to bars, plates, or sheets or drawn into wires. By this method aluminium covered aluminium alloy (alclad), copper covered steel, tin covered lead, stainless steel covered ordinary steel duplex articles are obtained.

CEMENTATION

In this process, articles of a base metal are packed in a box with the powder of the coating metal or alloy. The whole thing is heated for some time to a temperature just below the melting point of the more fusible material. This is done in an inert atmosphere. Calorising (coating of iron articles with aluminium), chromizing (coating of iron articles with chromium), sherardising (coating of iron articles with zinc), and siliconizing (coating of iron articles with silicon) are the cementation processes. Carburising of steel is also a cementation process.

ELECTROPLATING

In this process (Fig. 9.3), metal coating is deposited on a metal body by electric charges. A suitable bath of electrolytes is taken. The base metal is the cathode and the metal to be coated forms the anode. When the electrodes are dipped in the solution and current is passed, metal deposition takes place. This is governed by Faraday's laws of electrolysis. Thus articles are plated with chromium, copper, gold, nickel, silver and similar other metals. Following are some of the common processes of metallic coating.

Fig. 9.3. Electroplating shop

GALVANIZING

Coating with zinc, when it is done by the hot dip process, is called galvanizing (Fig. 9.4). Zinc is melted in a tank. The cleaned metal is kept dipped in it for a certain period of time which depends on the thickness of the coat desired. It can also be done as a continuous process in case of wire coil, rolled sheets, etc. In galvanizing the outer coat is of pure zinc and between the coat and the steel an alloy layer is formed. This alloy layer is principally FeZn coat and $FeZn_2$. This alloy layer or zinc coat is galvanic to iron and gives it protection. That is why the process is known as galvanizing. Zinc forms crystals when it cools and produces the spotted colour on the galvanized steel. Many steel articles such as water pipes, buckets, wire fences, metal roofing, etc., are galvanized for protection. Zinc coating can also be laid by cementation, electro-deposition and spraying processes.

TINNING

A widely adopted method of tinning is the hot dip process. The article to be coated is cleaned, fluxed and dipped in a bath of molten tin. The thickness of coating can be of the order of .0015 mm. Tin is an excellent coating material because it can be applied as a very thin and uniform coating on base metals. The tinned surfaces can be joined by solder. Food does not get toxic in contact with tin. So tinned cans (i.e., iron cans coated with tin) are extensively used in canning industry. Tinned plate is commercially produced for this and other industries. Tin is also used for coating copper wire, copper sheets, cast iron and other ferrous and non-ferrous items. Tin coating can also be given by electro-deposition process and spraying.

Fig. 9.4. Galvanizing shop

COPPER, NICKEL AND CHROMIUM COATINGS

Copper coating can be applied by spraying and electroplating. Copper-claded steel wires which are extensively used for electrical transmission have a steel core of high tensile strength and an outer copper case with higher corrosion resistance and conductivity. Thickness of deposition of copper can be attained to any desired extent by electric deposition process. The electrolyte used in a copper plating bath is either an acid solution of copper sulphate or an alkaline cuprocyanide solution. Copper is a good corrosive resistant, when used on steel, but it requires very thick deposition.

Nickel coat has both protective and decorative value. Moreover, it is wear-resisting and so is used for building up the worn parts. So nickel coat is extensively used on steel, iron and brass articles. This metal is deposited generally by electric deposition process. Now-a-days, spraying and cladding methods for depositing nickel are gaining ground. The solution in a nickel plating bath is composed of nickel chloride, nickel sulphate and boric acid. Nickel coating of a thickness greater than .04 mm. is a good protection against atmospheric corrosion. However, in practice composite deposition of nickel, copper and again of nickel is applied. The article is buffed (polished), cleaned, degreased and then dipped into the solution. It is connected with the anode. The cathode is pure nickel. Many automobile parts, bath-room accessories, propellers, turbine blades, etc., are nickel-plated to have decorative, protective and wear-resisting properties.

Chromium coating, like nickel coating, is extensively used for decoration, protection and wear-resisting purposes. Chromium, when exposed to air, forms chromium oxide which forms a thin layer on the surface of the metal and protects it from further reaction. It has got very high abrasion-resisting properties. Almost all chromium coatings are done by electrodeposition. The solution used in the plating bath is composed of chromic acid and a little amount of sulphuric acid. The fumes from a chromium bath are very poisonous and special care is taken for disposing off the fumes. To have better corrosion protection, articles are first under-coated with nickel or copper and nickel, and then finally coated with chromium. Many articles of common and industrial use are chromium plated.

VITREOUS ENAMEL COATING

This is non-metallic, inorganic coating applied on iron and steel. The articles to be enamelled are degreased and cleaned of rust and scales. The coating is done either by the dry or the wet process. The mixture is made by fusing quartz, feltspar with borax, soda ash, sodium nitrate, fluorspar, cryolite and litharge. The fused product is now ground to powder and mixed with water clay and colouring agent. Now the coat is ready for application, and either the article is dipped in the bath or the coating material is sprayed on the article. Then the articles are dried and burned in an enamelling furnace. Generally, three coats are applied. This is the wet process. In the dry process, the first coat is given by the wet process and then finely powdered fused coat is dusted twice over. The last two coats are fused on the surface of the article in an enamelling furnace. Generally, enamelled articles are used for food, dairy and pharmaceutical industries. Common utensils, stoves, table tops, bath tubs and refrigerators are also enamelled.

ANODISING ALUMINIUM

Aluminium or aluminium alloys

automatically get an oxide protection coating in contact with atmosphere. A thick coating of oxide can be obtained by putting the article in the anode and immersing it in suitable electrolytes. Chromic acid, oxalic acid or more commonly, sulphuric acid is used as an electrolyte. If the articles are to be coloured after having been anodised, they have to be dipped in a solution of organic die or inorganic pigments. These precipitate on the oxide film through pores. After the anodising and the colouring treatments, the coating is sealed by boiling the article in water or by heating it in contact with steam.

9.5 Organic Coatings

Painting, varnishing, lacquering and enamelling are common organic coatings used for both protective and decorative purposes. These coatings are generally applied by brush or spray. The thickness of a coat is usually .02 to .10 mm. There are many renowned paint manufacturers who produce these organic coats for commercial use. Intensive researches in this field have made it possible to produce organic coats of improved qualities.

PAINTING

Paint consists of dispersion of pigments in drying vehicles. The vehicles may be oil, water or rubber. Driers are used in paints for quickening film formation and hardening, whereas thinners are used for easier brushing and spraying. Ordinary paints are oil paints or enamel paints. Water paints are called distempers and are used in colouring room walls. Casein paints and rubber paints are also available. Sometimes a small amount of varnish is also used in paints to give the coat a harder and more durable finish. The oil in paints gets oxidised by air and forms a hard homogeneous film. This is the characteristic of a drying oil used in paints. As this oxidising action is slow, a paint may take a long time to dry. To accelerate drying, lead, manganese and cobalt compounds are used as driers. The pigments of a paint lie in suspension in oil. They have two main functions. The first one is to give a desired colour for a pleasing effect and the second is to prevent ultraviolet light from getting into the film and decomposing it. The important properties of a pigment are colour, bulking value, hiding power, oil absorption and particle size distribution. Table 9.1 shows different chemical compounds used as pigments for different colours. The bulking value of a pigment is expressed in gallons of paint per pound of pigment, i.e., it gives the idea of the volume occupied by a unit weight of pigment while being used in oil. The hiding power of a pigment depends on the difference between its refractive index and that of the vehicle. The oil absorption capacity of a pigment is the amount of oil needed to make a satisfactory paste. The particles of pigments have sizes between .1 to 5.0 microns in diameter. The proportion of pigment particles of different sizes is a very important factor for the strength of the film and life of the paint. Sometimes for better life, composite pigments are used. For example, for white paint, 60 per cent white lead, 30 per cent zinc oxide and 10 per cent other white pigments are used.

Oils for Paints

As already mentioned, oils are either mineral or vegetable and animal products. Animal and vegetable oils are generally fatty acids combined with (polyhydric) alcohols. These are generally classified into non-drying, semi-drying and drying oils. Drying oils are most suitable for painting. Semi-drying oils are never

used alone, but are mixed with drying oils in a suitable proportion. The most widely used oil for painting is linseed oil, which belongs to the group of dry oil. Others are tung oil, oiticia oil, perilla oil, dehydrated castor oil, etc. Soyabeen oil and some fish oils are the common semi-drying oils, used in industry for painting.

Driers

To accelerate the rate of drying, driers are added to drying and semi-drying oils for the manufacture of organic coats. Driers are the organic compounds of chromium, lead, manganese and vanadium. These are always to be used in the right proportion. For example, in the case of linseed oil, only 50 per cent lead drier and .05% manganese drier are used for the best effect.

Thinners

Thinners help the easy application of paint. They are required to act as solvents or diluents. As they evaporate, a thin and smooth film of pigments and oils is formed on the surface. Thinners which dissolve drying oil, resins and cellulose products are called solvents and those which do not dissolve these are called diluents. Generally, diluents and solvents are mixed in proper proportions to produce improved and less expensive thinners. Petroleum spirits, turpentine and hydrocarbons are important thinners. Common solvents for shellac are methanol and ethanol. Turpentine is very widely used as thinner for paints. A pine wood product is a clear volatile liquid which does not evaporate very rapidly. The time of evaporation is enough to allow the marks of painting brush to flow out and disappear. This is the reason for its wide use in painting. Turpentine dissolves all fatty acids, mineral oils, resin, beeswax, and paraffin wax only moderately. But some dry oils, nitrocellulose shellac resins are not soluble in it. Petroleum products with properties similar to those of turpentine are produced now-a-days. Petroleum spirits dissolve all fatty and mineral oils, except castor oil. Nor do they dissolve nitrocellulose. Other thinners are benzene, toluene, solvent naphtha. Organic liquids such as alcohol, ketone, esters and ether are used as solvents and diluents for nitrocellulose paints.

Varnishing

Varnishes are compounds of resin and oil. The ingredients are suitably mixed at a high temperature. Varnishes are much harder and more impervious to moisture and stop the ultra-violet light.

Enamelling

Pigments are mixed with varnish to stop ultra-violet intrusion. This is called enamelling. If a suitable coat of enamel is dried at a high temperature, it is called baking enamel.

Nitrocellulose Painting (lacquering)

Lacquer is a solution of nitrocellulose mixed with some resin in a suitable solvent. Lacquer can be applied only by spraying and is notable for its speed of application. The different solvents for lacquer have already been mentioned. Nail polish, cellophane coatings, etc., are some among the many products of lacquer.

Lacquer Enamelling

This is a process of coating in which pigments are used with clear lacquer. Lacquer enamelling is now very common in industry.

TABLE 9.1

Colour	*Pigment*	*Comment*
White	White lead $(PbCO_3)_2$ $PbOH_2$	Good hiding power
White	Sublimated white lead $(PbSO_4)_2$ $Pb(OH)_2$	
White	Titanium white TiO_2	Also used with other white pigments such as barium sulphate, magnesium silicate, zinc oxide, etc. Gives mechanical strength and longer life to coatings
White	Lithopone (70-75)% $BaSO_4$+ (30-35)% ZnS.	
White	Zinc oxide (ZnO_2)	Extremely effective to exclude ultra-violet light from coat
Blue	Prussian blue or Paris blue $Fe_4(Fe\ (Cn)_6)_3$	Great colouring power; resists action of ultra-violet light; gives glossy surface
Blue	Ultramarine (complex salt of sodium aluminium silicate and sulphide	Used as laundry blue; good for painting wood and not for iron (for its sulphur contents)
Blue	Cobalt blue (30-35)% Co_3O_4+(70-65)% Al_2O_3	
Green	Chrome oxide (Cr_2O_3) (Permanent green)	Brilliant dark green; not affected by light and atmosphere; very good covering power and hiding properties; expensive
Green	Chrome green (Prussian green) mixture of prussian blue and chrome yellow (lead chromate)	Good covering power; various shades of green can be obtained
Green	Paris green (copper acetoarsenite or arsenate)	
Yellow	Chrome yellow (mainly lead chromate Pb CrO_4)	Very brilliant;very good covering power and hiding properties; is mixed with other pigments for lighter and different shades
Yellow	Citron yellow (zinc chromate Zn CrO_4)	Good covering power; not affected by light and atmosphere
Yellow	Yellow ochre (natural pigment) $CaCO_3$ or clay+20% hydrated ferric oxide	Moderate covering power
Yellow	Cadmium yellow (CdS)	Also used with white pigment for lighter shades
Red	Red lead (Pb_3O_5)	Unaffected by light; tends to dry, so driers are not used; very good hiding power; extensively used as primary coats for steel structures
Red	Venetian red mixture of ferric oxide and calcium sulphate$(Fe_2O_3–CaSO_4)$	Very durable pigment and very good as protective for wood but not for metal
Red	Indian red or natural iron oxide (88 to 95% iron oxide and+clay.)	

Colour	*Pigment*	*Comment*
Red	Chrome red (basic lead chromate) $Pb_2(OH)_2\ CrO_4$	Used on metal; has excellent hiding power
Black	Lamp black (carbon soot 98% of pure carbon)	Very durable
Black	Carbon black Graphite (natural or artificial)	
Metal powders		
Aluminium	Aluminium powder	Good hiding power and impermeable to moisture
Bronze	Bronze powder	
Gray	Zinc dust $(Zn+ZnO_2)$	
Different shades	Lake pigments	Permanent in respect of light and atmosphere
	Organic colouring matter with suitable mineral	Used very much in painting

BITUMINOUS COATINGS

These relatively cheap coatings are coal products. These are widely used for protecting pipe lines and iron and steel structures which remain in contact with or buried under ground. These are extensively used on wood to protect it from white ants. Bituminous coatings are less permeable to moisture and are frequently used in concrete structure.

WAX COATINGS

It is a paste for polishing and finishing wooden furniture and floors, refrigerator and car bodies, etc. It is a mixture of hard wax and petroleum naphtha with or without turpentine. High grade polishing and finishing is obtained from the coating.

9.6 Application of Organic Coatings on Metal Surfaces

Generally metals have fairly smooth and non-absorbent surfaces. The primary or first coat which has more adhering qualities must be used. A very smooth surface is made rough to have increased adhesive power. The adhering property of the primary coating is due to gums, resins, or tung oil. Pigments are used in the primary coat to stop untra-violet light. Pigments for primary coats on iron and steel are red lead, zinc oxide, zinc chromate, lead chromate, etc. Composite pigments of iron oxide with a little amount of manganese dioxide and zinc chromate form very good rust preventive primer. Before any coating is laid, the metal surface should be cleaned carefully and made free from rust. Sometimes additional chemical treatment is given to form a passive film of oxides or phosphates on the metal surface. The articles must be free from moisture when the primary coat is laid. After this coat dries, one or two final coats are applied. If the article has not been properly cleaned or if the undercoat used is of inferior quality, peeling off of film will take place in a considerably short time.

In case of any difficult problem relating to protective and decorative coating, one should get in touch with coating technologists or paint manufacturing firms for their advice.

WORDS TO KNOW

Corrosion, Erosion, Casting, Pickling, Flux, Vitenous Enamel, Anodising, Thinner, Driers, Vehicles, Pigment, Peeling.

QUESTIONS

What is corrosion and why is it important in industry?
Differentiate between corrosion and erosion.
How does corrosion take place?
What are the ways to prevent corrosion?
How was corrosion prevented in old days?
How are metals treated before the application of casting and why is it so treated?

Name the different metal coating processes.
Describe hot dipping, metal spraying, metal cladding and cementation processes.
What is electroplating?
How are galvanising and tinning done?
Why and how are nickel and chromium coatings given?
What is vitreous enamel coating and how is it applied?
Why and how is aluminium anodised?

What are the common organic coatings?
Describe how the process of painting is done?
What oils are used for painting?
What are the uses of thinners and driers?
Explain how paints harden.
What is the special property of nitrocellulose painting?
What are the chemical pigments used for white, red and yellow colours?

CHAPTER 10

Simple Metallurgy

10.1 What is Metallurgy

Metallurgy is the art and science of procuring and adopting metals to satisfy human needs. It is the study of metals. One who does this work is called a metallurgist. Metals are available on the earth's surface in abundance, but most of them cannot be used in the condition they are found. In natural state, most metals occur in combination with non-metals, such as oxygen, sulphur, etc. These have to be freed from non-metals and obtained in a nearly pure state. Then they are recombined with other metals in suitable proportions, worked and treated under different conditions for various requirements.

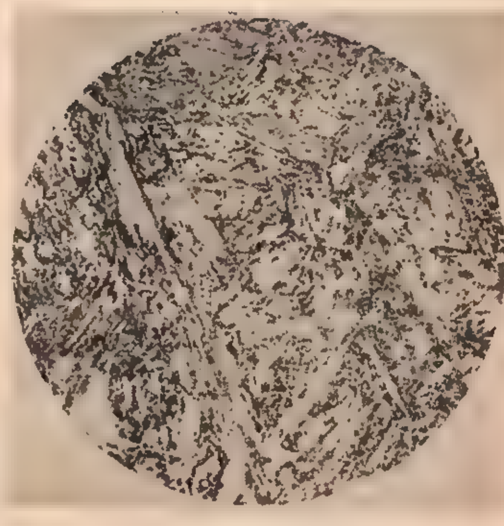


Fig. 10.1 Steel magnified x 2000

CHARACTERISTICS OF METALS

About forty of the chemical elements are classified as metals. The characteristic properties of metals are high electrical and thermal conductivity, ability to be permanently deformed and typical metallic lustre.

All solid metals are crystalline in structure, i.e., when a metal piece is broken, it looks like the broken face of a lump of sugar. The atoms of a metal are arranged in a definite (repeating) simple geometrical pattern of symmetry. Thus a lump of a metal is formed when a metal solidifies from the liquid state. At the solidifying temperature it starts to solidify at different points simultaneously in the aforesaid patterns and the solid crystals grow in size till they melt the adjacent crystals. So every crystal has its respective orientation. These small crystals are called grains. Their boundaries are called grain boundaries. If a portion of a commercially pure metal, suitably polished and reacted by some chemicals on the plane surface, is seen through a metallurgical microscope, similarly oriented areas and grain boundary lines are observed.

The mechanical properties of a metal depend on the grain sizes and structures (the pattern of arrangement), besides their chemical compositions. One of the jobs of a metallurgist is to study the structure of grains of metals and find out various treatments which will give metals the desired properties.

Whatever may be said about the geometric pattern of arrangement in metals, there are millions of flaws. These flaws in arrangement are helpful for manufacturing technology. It is known that the ability of deformation of metals is due to the presence of these flaws. The smaller the number of flaws, the harder a metal is. If the arrangement in a metal was perfect, some of the present processes of manufacturing (such as cold forging, cold rolling, etc.) would have been in the air.

ALLOTROPY

The crystal structures of some metals or alloys possess the capacity to undergo change. This property is referred to as allotropy and the change is called allotropic change. This allotropic change generally affects the various properties of metals.

10.2 Alloys

An alloy is a mixture of two or more metals (or at least one metal and a non-metal). It is a new material whose properties are different from those of the original metals. The colour, the melting point, the hardness and other physical properties of an alloy will be different from those of the constituent metals.

In metal working, metals and alloys are broadly classified under ferrous and non-ferrous groups. Steel alloys and cast iron alloys come under the ferrous group whereas alloys of aluminium, copper, gold, nickel, silver, tin, zinc, etc., are non ferrous alloys.

10.3 Ferrous Alloys

STEEL ALLOYS

Plain carbon steels are alloys of iron and carbon. This class of alloys has tremendous industrial importance. Iron and carbon combine to form Fe_3C which is a very hard, white and brittle substance. Steel is an alloy containing free iron and iron carbide. The more iron carbide a steel contains, the harder it is. When a plain carbon steel, after etching and polishing, is observed under a metallurgical microscope, you will notice that the steel has dark and white portions. The white portions are pure iron and the dark portions contain 87% of iron and 13% of Fe_3C (cementite). This dark substance is called pearlite which is very strong and adds to the strength of the steel. As the carbon content of steel is increased, the amount of pearlite also increases until when the steel contains .9% of carbon, and its structure is entirely of pearlite. Further increase will form more Fe_3C (cementite) which is brittle. So the steel gets harder and stronger up to the point at which it contains .9% of carbon; beyond this, the strength decreases. This iron base alloy is very important as it responds to heat-treatment for the change of properties which will be discussed later.

Special alloy steels are formed by the addition of one or more of the following metals besides carbon. These are chromium, manganese, molybdenum, nickel, tungsten, vanadium, etc. Addition of these metals in certain percentage gives rise to special qualities in alloy steels.

Chromium Steel

The metal chromium mainly adds toughness, hardness, anti-rusting and anti-

wear properties to steel. Stainless steels are high chromium steels, which have lasting silvery brightness. These steels are used for cutlery, cooking wares, instruments and decorative pieces.

Nickel Steel

The element nickel gives steel strength and toughness and anti-rusting properties to a certain extent. They are used for steel rails, automobile axles, armour plates, etc.

Nickel-chromium Steel

These steels are hard and tough and have good anti-rusting properties. They are used for armour-plates, gears, shafts, springs, etc.

Manganese Steel

The addition of manganese makes steel tough and strong enough to stand shocks, strains and wear. Manganese steel is used for shovels, ploughs, chains, gears, railway crossings, etc.

Molybdenum Steel

These steels are also called 'Molly steels'. These steels have special properties of withstanding shock and high temperature, in addition to having strength and hardness. These are used for ball-bearings and roller-bearings and high grade machinery components.

Tungsten Steel

Tungsten adds hardness to steel and enables it to stand high temperature. That is why tungsten steel is used for high speed cutting in which the temperature rises very high. Magnet steels also contain tungsten and these are used for electrical instruments. Tungsten steel is also used for armour plates.

Vanadium Steel

. Vanadium gives strength and toughness to steel and helps it to absorb shock to a great extent. This is used for axles and gears of automobiles.

High Speed Steel

This is an alloy steel containing carbon and one or more of the following metals: chromium, manganese, molybdenum and tungsten. This is a self-hardening steel and can retain its hardness even when red hot. This is used for single-point cutting tools, drills, taps, milling cutters, etc. It derives its name from its ability to cut material at a higher speed than plain carbon tool steel. The common high speed steel for cutting tools is 18:4:1 type, i.e., 18% tungsten, 4% chromium, 1% vanadium, .6% C and the rest iron.

10.4 Non-Ferrous Alloys

ALUMINIUM ALLOY

Aluminium is one of the most important elements which is used for some important alloys. Aluminium alloys are widely used. Aluminium forms alloys with small quantities of one or more of the following elements: copper, zinc, manganese, nickel, etc. There are several types of aluminium alloys. For tough casting, aluminium copper alloy with 12% Cu. is extensively used. With copper, nickel and magnesium, aluminium forms alloys which can retain good strength at high temperatures and which are used for piston rings. Duraluminum is another important alloy of aluminium containing copper, manganese and magnesium. This is widely used in forging, stamping, bars, plates, tubes, etc.

Aluminium bronze is an alloy of aluminium and copper. This alloy, having good strength and a fine golden colour, is used for imitation jewellery and decorative purposes.

BRONZES

Copper and tin alloys are known as bronzes. An alloy of copper, tin and zinc with specific properties is called gun metal. Gun metal castings are strong and resistant to corrosion when in contact with water or air. If a little phosphorous is added, it makes phosphor-bronze. It is an important alloy with wide use. One variety of it can be drawn into wire and rolled into strips. The other variety of phosphor-bronze can be cast and is strong enough to take heavy load. Bearing bushes, worm gears, nuts for lead screws, etc., are made of this alloy.

BRASS

This is an alloy of copper and zinc and has a light yellow colour. By varying the proportions of copper and zinc different varieties of brass can be manufactured. Brass does not corrode easily, and is used for door hinges, tower bolts, parts of watches, utensils, etc. One particular variety (gilding metal) with a high porportion of copper, has a very bright yellow colour and is used for cheap jewellery. Brass rods, tubes, plates, sheets and castings are also available.

SOFT SOLDER

This is a tin and lead alloy of approximately 50:50 proportion. This is used for hand soldering by a tinsmithy man. Other tin and lead solders are used for plumbing work.

BEARING METALS

These are tin or lead base alloys, i.e., in them either tin or lead is predominant. Tin base alloys are called babbit metals. Besides tin or lead, these white bearing metals contain antimony and copper. They are extensively used for bearings in automobile, aero-engines and locomotives.

PEWTER

This is an alloy of tin, antimony and copper. This is used for table-wares and utensils in our country.

MONEL METAL

This is a nickel and copper alloy. This alloy is strong, does not rust and shines like silver. This is used for propellors and cooking equipment.

GERMAN SILVER

An alloy of copper, zinc and nickel, German silver is used as a substitute for silver. Inexpensive jewellery and table-wares are also made of this alloy.

SILVER ALLOY

As pure silver is soft, an alloy of this metal is used for ornamental work, jewellery, mirrors and coins. Sterling silver contains silver and copper. It is used for jewellery and table-wares.

GOLD ALLOY

Gold is the noblest metal. Precious, bright yellow in colour and very soft, it is alloyed with silver and copper for use in jewellery, ornaments, coins, etc. The purity of gold is measured in carats. Twenty-four carat gold is of the purest quality. Fourteen carat gold means, 14 parts of gold and 8 parts of copper or silver. Guinea gold is of 22 carats.

10.5 Some Important Properties of Metals

HARDNESS

It is the measure of the ability of a metal to withstand scratching, abrasion, wear and indentation by other hard bodies. Hardness is measured by the amount of indentation made by a diamond or a steel ball. Hardness goes with brittleness in general, i.e., the harder a substance, the more brittle it is.

TOUGHNESS

Toughness is the amount of energy a metal can absorb before it breaks.

STRENGTH

The strength of a metal is its ability to resist the application of force without rupture. The applied force may be tensile, compressive or shear.

If the applied force stretches a body it is known as tensile force; if it compresses the body, it is called compressive force. The force is called a shear force when it acts tangential to the surface on which it is applied.

BRITTLENESS

Brittleness is breaking of a thing without much permanent distortion. Glass is harder than steel but less tough, so it is more brittle than steel.

ELASTICITY

The ability of a metal to return to its original shape after deformation by force is called elasticity. The applied force may be tensile, compressive or shear or may be of hydro-static type.

PLASTICITY

This property is opposite to elasticity and involves permanent deformation without rupture under applied force. It is the permanent flow of metal under load without fracture.

MALLEABILITY

Malleability is the property of a metal to extend permanently in all directions without fracture under compressive load, i.e., pressing, hammering, rolling, etc. Lead is very malleable. It is plastic without having much strength.

DUCTILITY

It is the property of a metal to be drawn into a wire, i.e., it may extend without rupture under tensile load. The metal should be plastic but should have strength like gold, copper, etc.

10.6 Simple Heat Treatment

CRITICAL TEMPERATURES

It is observed that when iron base alloys are heated or cooled over a temperature range, certain arrests (constant temperature for some time) of heating or cooling occur owing to allotropic changes in iron, the change of structure requiring or liberating some heat energy. The temperatures which correspond to these heat effects are known as critical temperatures. When a steel is heated to the critical temperature, it undergoes allotropic modification and the grains become very fine, i.e., the crystals become smaller. This critical temperature is different for different kinds of steel and depends on the amount of carbon in the sample. The higher the carbon content, the lower is the critical temperature. These critical temperatures

are experimentally obtained for steels of various carbon percentages. At the critical temperature, a steel loses its magnetic properties.

10.7 Object of Heat Treatment

The object of heat treatment of steels is to alter their physical properties. It is not the only means, some physical properties can also be changed by mechanical working which will not be discussed here. Heat treatment may involve a variety of processes which have as the end result a distinct altering of the internal structure, or a change in the distribution of the ingredients present. The thermal treatment leads to (i) softening, (ii) toughening, (iii) hardening and strengthening, (iv) changing of grain sizes, and (v) removal of internal strains due to distorted arrangements of atoms. These objectives are achieved by the heat treatment processes known as annealing, normalising, hardening and tempering.

High Carbon Steel: Steels with .7% to 1.4% carbon are known as high carbon steels. These are used for various purposes, including making of cutting tools and, as such, they are also called tool or cast steel. It is known that steels with carbon content of .1%—.7% are low carbon steels which comprise dead mild steel and medium carbon steels. Carbon 2 – 4½% remains in cast iron, both in combined and free state.

APPLICATION OF VARIOUS HIGH CARBON TOOL STEELS

Carbon content	*Typical application*
.70%	Hammering tools, forging dies, shear blades, springs.
.90%	Lathe centres, punches, cold heading dies.
1.00%	Blanking dies, broaching tools.
1.10%	Lathe tools, drills, reamers, taps and dies.
1.20%	Lathe tools, razors, wood working tools.
1.30%	Drawing dies, hand files, gauges.

10.8 Heat Treatment Process

ANNEALING

The purpose of annealing is to soften the metal for easy machining and to relieve the internal stresses. This is the opposite of hardening. The process is, first, to heat the steel slowly to a little above the critical temperature and then to keep it for some time (soaking) for allowing the internal changes of structure to take place and finally to cool it as slowly as possible. The slower the cooling, the softer would the steel be. It is cooled in the furnace away from air after it is shut off. The steel is also cooled slowly after being packed in hot ashes so that it is not allowed to come in contact with air. Castings and both low carbon and high carbon steels are annealed in this way.

APPROXIMATE ANNEALING RANGE FOR STEEL

Carbon %	*Annealing temperature in °C*
.1 —.12	875—925
.12—.25	840—870
.3 —.5	815—840
.5 —.9	780—810
.9 —1.3	760—780

Copper and brass can also be annealed to soften. These are heated till rainbow

colours appear on them, and then they are dipped in water.

NORMALISING

The purpose of normalising is to refine the structure of steel and remove the strains caused by mechanical working in cold, i.e., hammering, rolling, bending, etc. The steel is heated above the critical temperature, a little above the annealing range, and is followed by cooling in still air at ordinary temperature. The process is quite similar to annealing in a general way but the temperatures are higher and the cooling is somewhat faster than that in annealing. This treatment removes strains and imparts homogeneous structure, moderate hardness and strength to steel.

HARDENING

High carbon steels are hardened in the following way. A steel piece is heated slowly to a little above the upper critical temperature and is suddenly cooled in oil, water or other liquid medium. Due to rapid cooling, certain changes in the internal structure of the steel make it hard. Hardness brings brittleness and removes toughness. But in cutting tools, both hardness and toughness are required to certain degrees. The degree of hardness of a steel depends on the carbon percentage, hardening temperature and rate of heating and cooling.

TEMPERING

The purpose of tempering is to impart toughness to a hardened piece of steel at the cost of hardness or brittleness. This is absolutely necessary for the practical use of the steel piece. If it is very hard, it becomes very brittle too and breaks easily while in use. This process is applied to a hardened piece of steel. The piece is brought to the tempering temperature (see table) and then it is quenched in water and moved round. The temperature of water should be between 30° to 40°C. It can also be quenched in oil. Sometimes in workshop the colour of the oxide film on the steel piece denotes the temperature it has attained. Experienced workers in the shop can give heat treatment satisfactorily without any instrument for measuring temperature. The tempering temperature varies according to the use of the tool.

Tools	*Tempering temperature* °C	*Colour*
Lathe tools	230	Pale straw
Drills and milling cutters	240	Dark straw
Taps and shear blades	250	Brown
Punches, reamers, riveting tools	260	Brown purple
Press tools	270	Purple
Cold chisels	280	Dark purple
Springs	300	Blue

WORDS TO KNOW

Thermal Conductivity, Electrical Conductivity, Crystals, Crystalline, Structure, Orientation, Grain Boundary, Flaws, Deformation, Allotropy, Alloys, Perlite, Ferrite, Cementite, Critical Temperature, Annealing, Normalising, Hardening, Tempering.

QUESTIONS

What is Metallurgy?
How does a metal change from the liquid to the solid state?
What are grains and grain boundaries?
On what do the mechanical properties of the metal depend?
Why does a metal become deformed?

What is allotropy?

What is an alloy?
State the properties of some alloys, making a comparative study of the properties of their constituents.
What do you know about ferrous alloys and non-ferrous alloys?
What are the main constituents of steel?
What makes the steel hard?
Indicate the importance of carbon in steel.
How are special properties added to steel by alloying other metals with it?
Indicate the special properties added to steel by chromium, manganese, molybdenum, nickel, tungsten and vanadium.
What are the metals used to form the important non-ferrous alloys? Indicate their use.
Write in simple language about the different mechnical properties of metal.

What is critical temperature?
Why is it so important?
What happens when steel is heated to the critical temperature?
Why are metals and alloys heat-treated?
What is heat treatment?
How are the following heat treatments done—annealing, normalising, hardening, tempering plain carbon steel?
Write the various uses of plain carbon steel.
How is a cutting tool of plain carbon steel manufactured?

CHAPTER 11

Common Engineering Components

11.1 Introduction

Metal workshops, as the name signifies, are places for working on metals. The aim is to shape and produce components of utility. The correct production of the items depends on suitable raw material, right tools, machine tools, correct process and the skill of the personnel in the shops. All the items except the first one, have been discussed elsewhere in this book. Raw material will be discussed in this chapter.

Generally the finished components of one shop form the raw material for another. For example, castings are finished components of the foundry shops but are raw material for the machine shops. Similarly, the forgings produced by a forge shop are utilized as raw materials for the machine shops. Again, an assembly shop requires all finished components of other shops as its material to work with.

It is neither possible nor economical for a manufacturing concern to produce each component of its product from the basic raw material. It has got to depend on other firms who specialize in the processing of certain items. For example, an electric motor manufacturing concern generally procures bolts and nuts, winding wires, bearings, stampings, steel sections, insulating materials, paints and greases, etc., from concerns specializing in the manufacture of these items. If it wants to produce everything itself, it would be making an absurd proposition. This co-ordinated and integrated approach to manufacturing builds up the industrial complex of a country. This interdependence ensures quality and achieves economy in the production of engineering components. Thus, items like bolts and nuts, rivets, washers, springs, split pins, bearings, etc., are purchased from concerns producing them. A general metal workshop must have in stock all these items along with various tools and equipment. But some items are more necessary in certain shops than in others according to the nature of work. Electrodes, brazing rods, fluxes, etc., are used chiefly in the welding shop; nails, wood screws, hinges, etc., in the carpentry shop and so on. Lubricating oils, coolants, cotton waste and cleaning material are important items which should be procured for all shops.

PRODUCT MANUFACTURE

In a manufacturing concern, a product is designed by designers for manufacture in shops. The designers consider the working of the product, life, and strength, and so select the types and fabricated

forms of material for each component and recommend the heat treatment. They ultimately produce working drawings giving details of dimensions, material and treatment which are forwarded to manufacturing workshops for production and fabrication. This is the usual practice. After the drawings are received, the bill of material, manufacturing procedure and tools required are prepared. The bill of material is a summary of the working drawings indicating the numbers and names of all parts, the type, size, fabricated form and the quantity required with cost of assembly. It also indicates which finished components are to be purchased and which are to be manufactured in the concern. So this bill guides the purchase department to procure finished components and raw materials for the product. In general it can be said that for manufacturing, a shop procures some hardware and standard parts such as bolts, screws, strips, etc., and stock materials. Stock materials are machined to finished articles. For example, a half inch round mild steel is the stock material for producing half inch studs.

FABRICATION OF ENGINEERING ARTICLES

In any fabrication or assembly work of a product, we come across two situations. Two or more components may have to be either fixed relative to one another or assembled to have desired relative movements. As such the whole area of assembly can be divided into two sectors—fastening and bearing. In the first kind of fixture, fasteners are used and in the second, guides (bearings) are used. Fasteners and bearings are themselves engineering components which deserve special consideration.

11.2 Raw Materials for Machine Shops

Steel manufacturers produce steel sections for different industries. The sections are standardized for all manufacturers in a country. Standardization means that the products of a steel plant should conform to definite sizes, shapes, composition and mechanical properties. Thus products from all steel plants will be similar and it should be possible to use them as alternatives. This standardization helps to coordinate manufacturing and ensures easy control. Not only in steel making but in other spheres too, standardization is absolutely necessary. The government of every country has set up a Standard Institute to lay down the standards of the components and raw material and to control them. In our country also, the Indian Standards Institution has been formed after independence for the purpose.

Steel sections are available as sheets, plates, strips, bars of various cross-sections, rounds, angles, channels, I-Beam, Tee, etc. (Fig. 11.1). The Indian Standard follows the metric system. The specifications are as follows:

Plate—ISPL (Length x Width x Thickness)

Length in mm.—2200, 2000, 2800, 3200, 3600, 400, 4500, 5000, 5600, 6300, 7100, 800, 9000, 10000, 11000 and 12500.

Width in mm.—900, 1000, 1100, 1200, 1250, 1400, 1500, 1600, 1800, 2000, 2200 and 2800.

Thickness in mm.—5, 6, 8, 10, 12, 14, 16, 18, 20, 22, 25, 28, 32, 36, 40, 45, 50, 56, 63.

Example: ISPL 2200 x 1000 x 8

Sheets: ISSH (Length x Width x Thickness)

Length in mm.—1800, 2000, 2200, 2500, 2800, 3200, 3600 and 4000.

Width in mm.—600, 750, 900, 1000, 1100, 1200, 1250, 1400 and 1500.

Thickness in mm.—.40, .50, .63, .80, .90, 1.00, 1.12, 1.25, 1.40, 1.60, 1.80, 2.00,

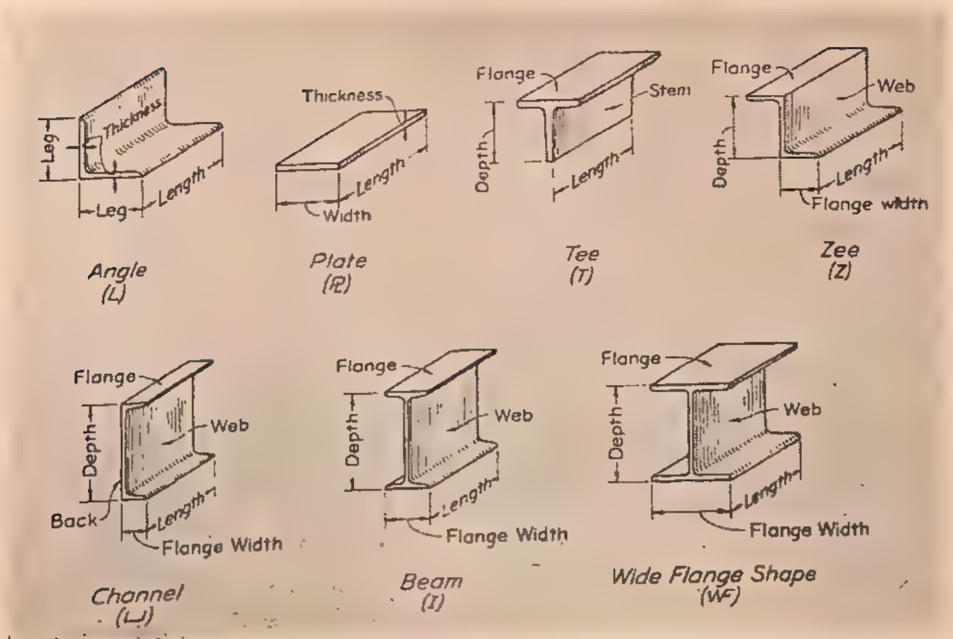


Fig. 11.1 Rolled sections

2.50, 2.80, 3.15, 3.55 and 4.00.
Example: ISSH 2000 x 750 x .50.
Strips: ISST—Width x Thickness.
Width in mm.—100, 125, 160, 200, 250, 320, 400, 500, 650, 800, (950, 1050, 1150, 1250, 1300, 1450, 1550).
Thickness in mm.—1.60, 1.80, 2.00, 2.24, 2.50, 2.80, 3.15, 3.55, 4.00, 4.50, 5.00 6.00, 8.00, 10.00.
Round and square steel bars: Round bars—ISRO (Diameter in mm.)
Diameter in mm.—5, 6, 8, 10, 12, 16, 20, 25, 28, 32, 36, 40, 45, 50, 56, 63, 72, 80, 90, 100, 110, 125, 140, 160, 180 and 200.
Square bars—ISSQ (Side width in mm.)
Side width in mm.—5, 6, 8, 10, 12, 16, 20, 25, 32, 40, 50, 63, 80, 100.

Standard sections of sheets, strips, bars, etc., of brass, copper, aluminium and other metals are also available for use in industry.

Castings and forgings of various shapes and sizes are brought to the machine shop for being machined to various dimensions. These constitute the raw material for the machine shop. Besides these basic raw materials, various engineering components such as bolts and nuts, studs, rivets, belts, pins, etc., also serve as raw material in the these shops.

11.3 Engineering Components

FASTENERS

These are gadgets for holding two or more metal parts together. Various types of fasteners are available in workshop for use in different situations. The common fasteners are rivets, bolts and nuts, keys and cotters, etc.

RIVETS

These are metal pieces (Fig. 11.2) used to hold work pieces together permanently. Unless rivets are cut off, the pieces cannot

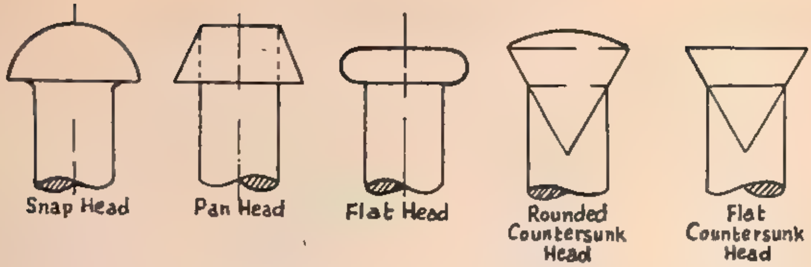


Fig. 11.2 Types of rivets

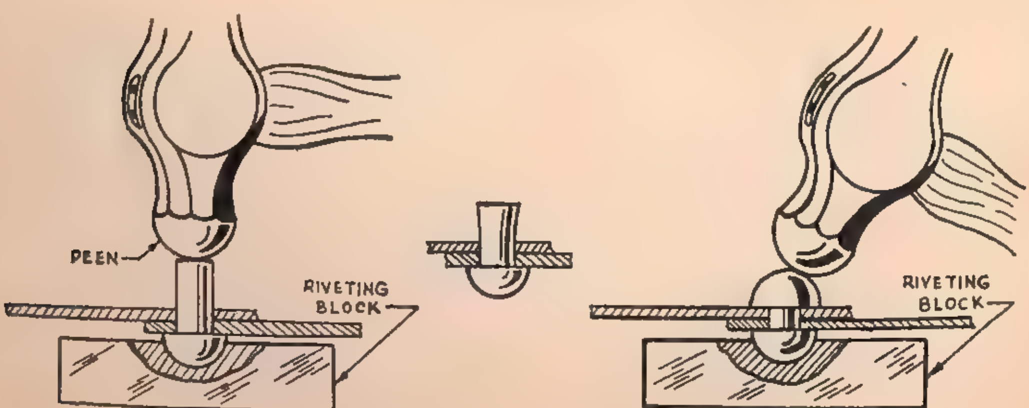
be separated. The operation of fastening with metal pieces is called rivetting. The metal pieces look like bolts without thread on them. They are named according to the shape of their heads (Fig. 11.3). Snap head rivets are used in structural work and machine rivetting. Pan head rivets are used when space is restricted and rivetting is done manually. For flush rivetting counter-sank rivets are used.

The specification of a rivet is given by the diameter and length of its body and the shape of its head. The length does not include its head.

Rivetting Operation

To fasten two pieces together by rivetting, the following procedure is adopted. The points on the pieces where rivets are to be placed are marked and punched. Holes are drilled at these points, the sizes of the holes being about .1 to .3 mm larger than the diameter of the rivets to be used. Rivets of proper length are chosen so that they have enough material projected outside the hole to form a head on the other side. A rivet is put through the hole and the head is supported by a rivetting block at the end, as shown in Fig. 11.3. Now the projected end should be hammered with the ball peen head of a hammer in order to form the rivet head. Sometimes rivetting tools are used to form heads of rivets. For the sake of economy, holes for rivetting are made in sheet metal by punching rather than by drilling. Rivetting is done either cold or hot. In cold rivetting, the head is formed by cold working of metal. In this kind of working, the material of

Fig. 11.3 Rivetting



rivets should be soft for easy work. For hot rivetting, a rivet is heated red in a furnace. It is then put through the hole. In the red hot condition, the head is formed and rivetting is completed. In hot rivetting, care should be taken to make big holes in pieces to allow the expanded rivets to pass freely through the holes.

Types of Rivet Joints

There are two main types of rivetted joints: (a) lap joint, (b) butt joint. In lap joint, pieces are connected in such a manner that the ends of the two pieces overlap each other (Fig. 11.4). In butt joint, pieces are rivetted so that their ends butt against each other (Fig. 11.4) where one or two cover straps are used for rivetting. The rivets in joints are used in single, double or more rows, and the joint is named accordingly; for example, single rivetted lap joint or double rivetted butt joint and so on. The distance between the centres of the two succeeding rivets in a row is called the pitch of the rivet joints. This pitch for a rivetted joint is determined from the strength of the rivet material and plate material.

Efficiency of a Rivet Joint

Efficiency of a rivetted joint is expressed by the ratio of the strength of the joint to the strength of the solid plate. It is expressed as percentage strength of the joint. It depends on the combination of dimensions and the type of joint.

THREADED FASTENERS—BOLTS AND NUTS

In comparison with the permanent methods of fastening such as welding and rivetting, threaded fasteners have the advantage that the components can be unfastened when desired. The threaded fasteners have screw threads and work according to the principle of bolts and nuts. These fasteners have various application in mechanical technology. As distinguished from other devices of fastening such as pins, rivets, keys, etc., a threaded fastener has a helical ridge on a cylindrical surface. The screw part has thread at one end and usually a head at the other. The nut has only a hole with a proper helical ridge. Many varieties of fasteners are obtainable. Some of them have been standardized but special sizes are also available. The name

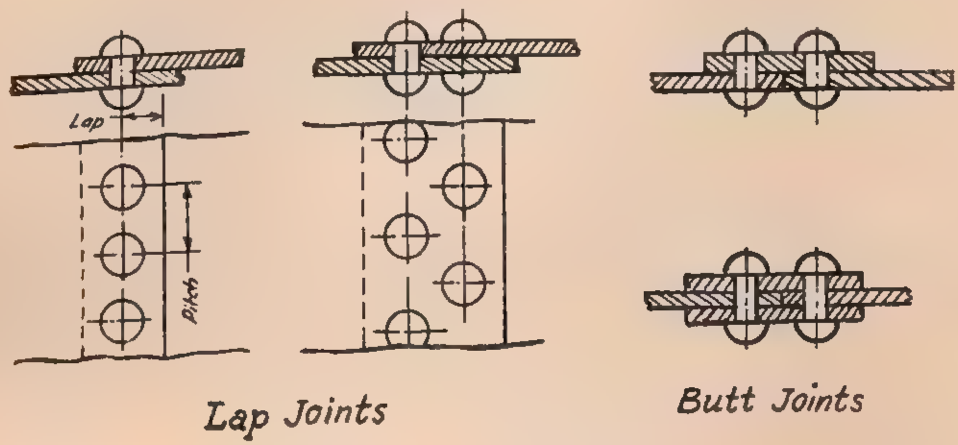


Fig. 11.4 Types of rivetted joints

'bolt' has presumably been derived from the use of this type of fasteners for bolting a door.

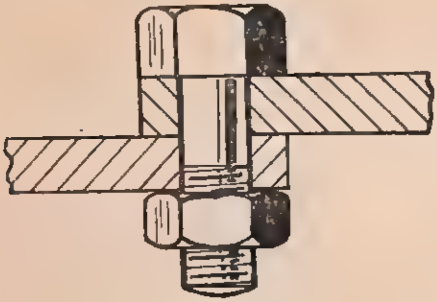


Fig. 11.5 Bolt Joint

Threaded fasteners can be broadly divided into five groups, namely, bolts, cap screws, machine screws, set screws and studs. A bolt has a cylindrical body threaded at one end and has an integral head at the other end. It is pushed through clearance holes between the two parts to fasten them togehter with the help of a nut at the threaded end (Fig. 11.5).

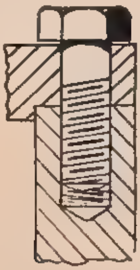


Fig. 11.6 Cap screw Joint

A cap screw is similar to a bolt. It is made to pass through the clearance hole in one piece and is fitted in the screwed hole of the other. When turned, the cap screw enters the threaded hole and draws the parts together till it finally fastens them (Fig. 11.6).

A machine screw is generally of a smaller type with round or cheese head and is used with a nut to function as a bolt or without a nut to function as a cap screw.

A set screw fits a tapped hole in a hub or outer part and fixes the shaft inside the hub at a proper position (Fig. 11.7).

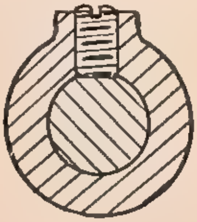


Fig. 11.7 Set screw joint

A stud is a rod threaded at both ends. It is screwed permanently in one piece. The second piece has a clearance hole which passes on the stud and the two are fastened together by means of a nut (Fig. 11.8).

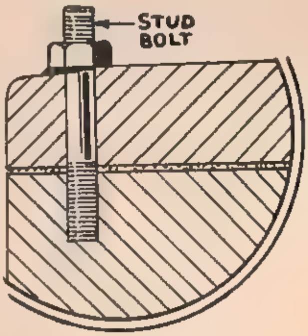


Fig. 11.8 Stud Joint

The details of various standard screws may be had from the drawing book or any workshop handbook. The Indian Standards are in the C.G.S. units.

Threaded fasteners are also available in modified shape to be used in various places. These are collar screws, thumb screws, hook bolts, U-bolts, eye bolts, turn buckles, wing nuts, etc. (Fig. 11.9).

Lock Nuts and Locking Devices

When two pieces assembled by threaded

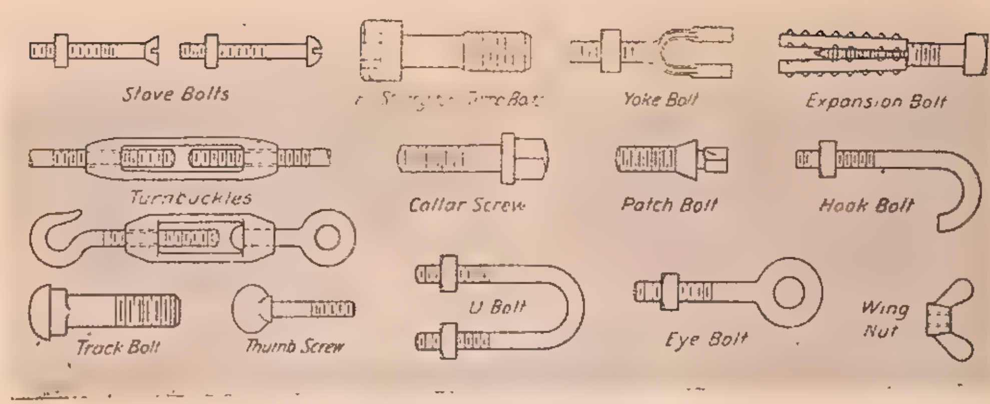


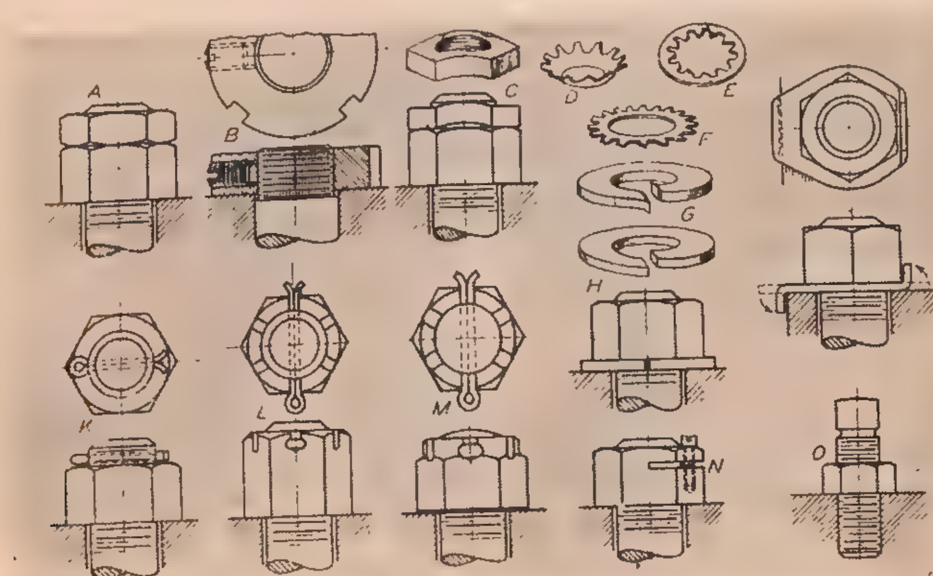
Fig. 11.9 Modified thread fasteners

fasteners are subjected to shock and vibration as in an automobile engine or an aircraft, fastenings often get loosened. Different locking devices are used to prevent nuts or bolts from getting loosened. The common devices are things of fan nuts, slotted nuts, castle nuts, as shown in Fig. 11.10. Spring washers of a special type are also used for locking. The locking action prevents the screw or nut from moving by absorbing vibration.

KEYS AND COTTERS

These are common items of fastening a shaft and pulley, a shaft and gear or two shafts for transmission of motion. In the shaft and also in the gear or pulley, key ways are machined to accommodate a key which will fasten the male and female parts. The size of the key is determined by the power transmitted. The dimensions are made to give the right type of fit in the

Fig. 11.10 Locking devices of nuts



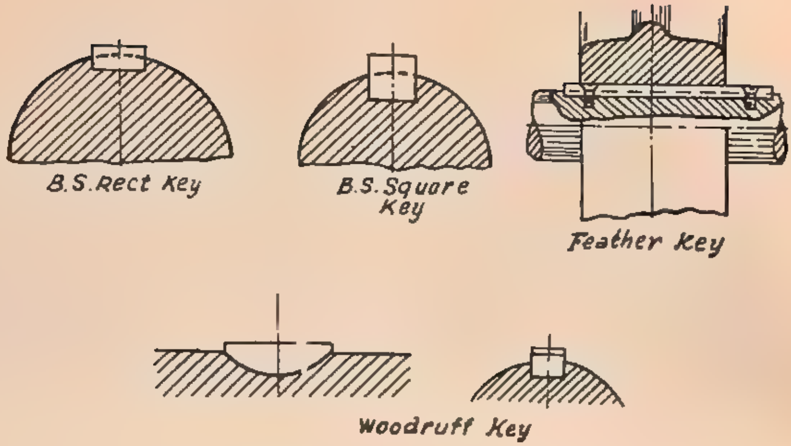


Fig. 11.11
Types of keys

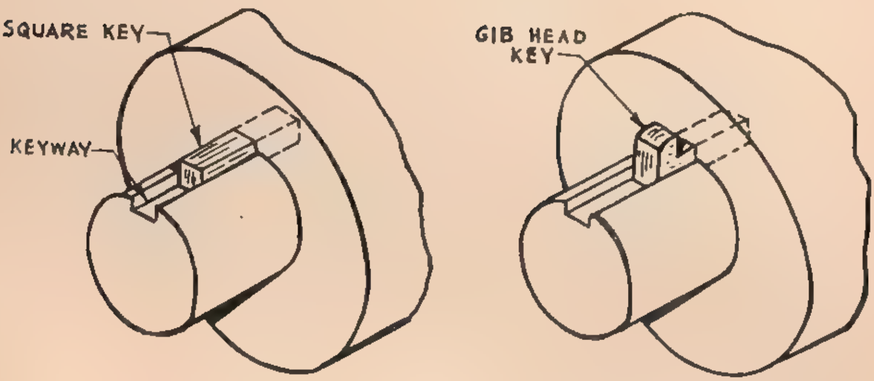


Fig. 11.12 Fastening by keys

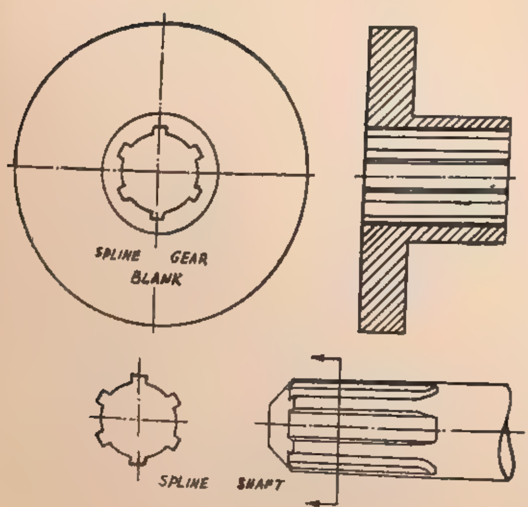


Fig. 11.13 Fastening by splines

assembly so that both axial and rotational relative movements between the rotating parts are stopped. Keys are standardized and different types are used in industry (Figs. 11.11 and 11.12). Fastening by splines is shown in Fig. 11.13.

Cotters are used perpendicular to the axis of the connecting pieces, unlike the keys which are used parallel to the axis. These are wedge-like in form (Fig. 11.14).

COUPLINGS

These are gadgets for joining or coupling two shafts end to end, so that their axis are collinear. These are generally used for joining two or more shafts to make a

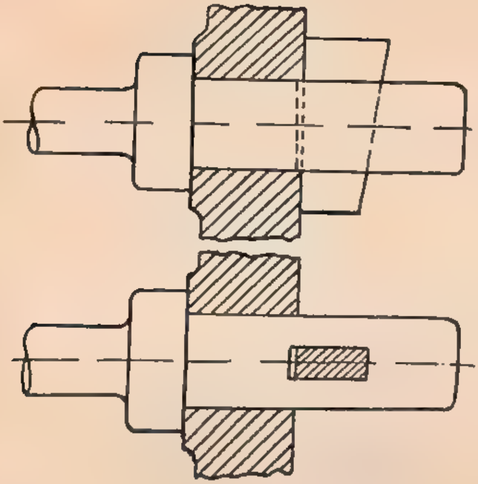
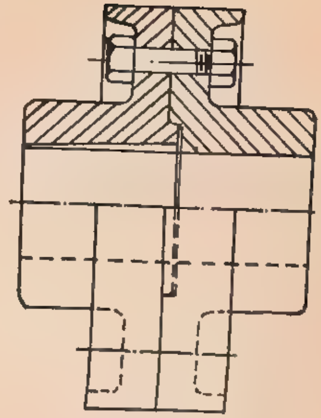
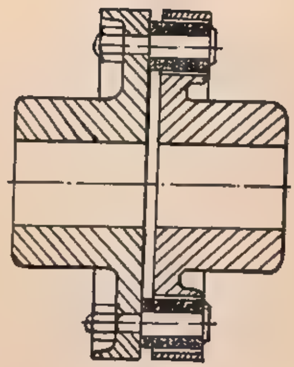


Fig. 11.14 Fastening by cotters



FLANGE COUPLING

Fig. 11.14 (a)



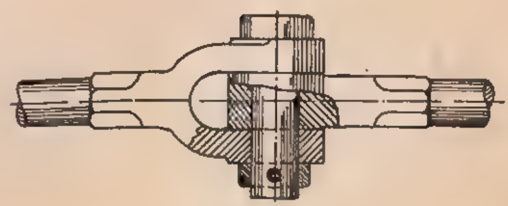
FLEXIBLE COUPLING

Fig. 11.14 (b)

long line-shaft. Couplings may be rigid or flexible. Flexible couplings are used between prime movers and electric motors or between machines and electric motors. The purpose of keeping flexibility in coupling is to absorb shocks and to allow the two shafts to vary a little from their axial alignment. Rubber grommets are generally used in flexible coupling (Fig. 11.14(a) and 11.14(b)).

Knuckle Joint

This is a type of joint connecting two round bars so as to permit axial adjustment on one plane. Fork and eye are made at the end of rods and are fixed by means of pins (Fig. 11.15).



KNUCKLE JOINT

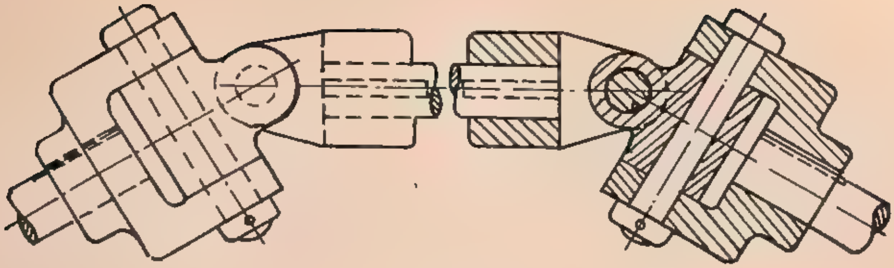
Fig. 11.15

Hooke's Joint or Universal Joint

This is a type of coupling which connects shafts at angles. By this joint, rotation is transmitted to shafts at various angles (Fig. 11.16).

Clutch

This is a type of coupling which may work on friction or positive engagement. The friction clutches may be conical or disc shaped. When the face of the element of clutches is pressed together, the friction force generated is used for driving, and when released the driver and driven shafts are separated. These are very commonly



HOOKE'S COUPLING

Fig. 11.16

used in machine tools, automobiles, etc. Positive clutches are claw clutches where the teeth of the two parts are engaged for coupling. These are used for slow transmission.

BELT DRIVES

Belts and pulleys are generally used for transmission of rotation. The pulleys are connected by means of belts either directly or cross-wise so that the rotation may be similar or opposite. The pulleys for flat belts are crowned a little and the belts are fitted with tension, so that the slip of belt is reduced during transmission of motion. V-belts on grooved pulleys are used to increase contact surface between belts and pulleys in transmission of high power. Assuming that there is no slip, the revolutions of two pulleys connected by a belt will be inversely proportional to their diameters (Fig. 8.2). Flat belts are generally made of leather or canvas. V-belts are made of rubber strengthened by woven canvas threads or steel wires.

BEARINGS

Bearings are used to support rotating shafts in position and with minimum friction. Bearings may be of slide type or rolling type. Journal bearings or thrust bearings are of slide type. The first one is used for supporting a shaft at right angles to the axis and the second one for supporting a shaft at the end and for bearing the thrust.

Slide Bearings

Slide bearings are made of gun metal, phosphor-bronze or white metal. These are very good bearing metals. Bearing metal having small friction and good oil bearing capacity is considered good, for these two factors reduce the wear. Proper lubricating oil is always used in slide bearings.

Ball and roller bearings are hardened pieces of special steel. A set consists of an outer race and an inner race and some rollers or balls running between them. Various standard sizes of these are available in the market. The manufacture of a ball bearing is a very precision job and special factories are set up to produce them. Rolling friction is less than sliding friction, so ball or roller bearings are extensively used in driving parts. Proper grease is used for lubricating these bearings. They have much longer life and lower cost of maintenance than slide bearings. (Fig. 11.17)

GEAR DRIVES

Gears (Fig. 8.5) are toothed wheels, and are extensively used in drives. The teeth have special forms so that when

Fig. 11.17 Section of ball bearing

engaged, the transmission is uniform and with little friction. For high precision transmission, the teeth are shaped very accurately by grinding and other fine finishing methods. These give positive transmission without slip, and are used when geometrical and kinematic accuracy is required. Sometimes gears are hardened to have longer life. Various types of gear, such as spur, helical, bevel and worm gears are extensively used in machine tools, automobile, aircraft and other transmission units.

WORDS TO KNOW

Castings, Forgings, Winding Wires, Bearings, Stampings, Electrodes, Brazing Rods, Flux, Product, Rivet, Lock Nut, Cotters, Couplings, Hooke's joint, Universal Joint, Belt Drive, Gear Drive.

QUESTIONS

What is meant by raw material of a shop? Illustrate.
Why does not one engineering firm produce everything itself?
What is a bill of material?

What types of joints do you come across when building up or fabricating a product?

Sketch some of the common steel sections.
How are steel sections specified? Give examples.

Name some of the fastening arrangements.

Sketch some of the rivets which are commonly used.
Describe how rivetting is done.
What are the main types of rivet-joints? Sketch.
How does a threaded joint differ from a rivetted joint?
Sketch some special types of threaded fasteners.

Why are locking devices used with threaded fasteners?
What is the function of a lock nut?
Sketch some locking devices.

What is a cotter joint?

What are couplings and why are they used? Name some couplings.
Sketch a knuckle joint and a Hooke's joint.
What is the function of a clutch?

What are meant by belt drives? Give examples of belt drives you have seen in shops.
How does a V-belt differ from a Flat belt?
State the application of V-belts.

Why bearings are used? Classify the bearings.
Name some of the common bearing materials.
Why ball and roller bearings are used instead of slide bearings.

Give examples of some gear drives used in shops.

CHAPTER 12

Electricity for Workshop and Domestic Use

12.1 Introduction

In modern workshop practice electricity is indispensable. Machines and plants of all shops use electricity in some form or other. Electric motors are in frequent use as prime movers to drive machine tools, line-shafts, air compressors, blowers, water pumps, etc. Electric lamps improve lighting conditions inside factory buildings, exhaust fans provide better circulation of air. Air conditioners control temperatures. Modern system of workshop management recommends provision of radios as a means of recreation to the workers during break hours. Telephonic connections are common means to link up the different shops. Electricity is therefore rightly called 'Power'.

SOURCES

Provision of electric power is possible by (i) generating electricity or (ii) by obtaining power supply from an electric supply company. In most organizations the latter system of power supply is adopted for reasons of economy. Bulk supply is received from the supplying company at a *commercial rate*. This is much cheaper than the rate for domestic supplies.

12.2 Commercial Generation and Transmission of Electric Power

Electric power is generated in power houses all over India. Power stations are generally classified into two broad sections—Thermal power stations and Hydro-electric power stations. Modern science has helped the development of a third section, namely, Nuclear power stations. These use atomic energy through *Reactors* to supplement the energy of heat. Although there are a few atomic power stations in advanced countries, there is only one under construction in India and that is the Tarapore Station in Gujarat.

Thermal stations use coal or oil as fuel to generate steam in boilers to drive the *turbine*. But hydro-electric power stations use the water running through the *pen-stock* to drive the water turbine coupled with the generator for producing electricity. In small-scale power houses, diesel engines are used to drive the generators.

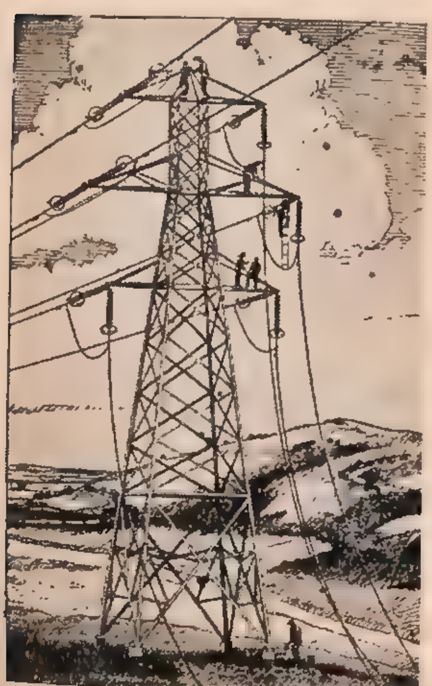
Power stations have been in existence to supply electricity to the various parts of India and to the industries established near about the towns. After Independence, the country is becoming more and more industrialized. Power supply has, therefore, increased tremendously to meet the demands of this industrial

development and for rural electrification. New power stations have been established in almost all states of the country with generators of up to 100,000 KW capacity. Electrical power is generated at high voltages, e.g., 6,600 volts, 11,000 volts and 33,000 volts. More power stations are under construction or are proposed to be constructed.

Particulars about the sites of these new power stations are given in the Appendix.

The generating stations in a particular zone are connected by a *grid system* of transmission lines. Power is supplied to the consumers through various stations located at different places in the zone. Power is transmitted through *high tension* (H.T.) transmission lines to distant places. Power transmission is made normally at 66,000, 132,000, 222,000 and 380,000 volts. Overhead lines are drawn, supported at regular distances by transmission towers across fields and villages and ending in the industrial area. (Fig. 12.1.)

Fig. 12.1 Transmission tower



Transmission of power at such high voltage has some unique advantages. The power transmitted in any circuit is governed by the product of the voltage and current which is $=E.I. \cos \phi$. Therefore, for transmission of the same power, the value of current will be smaller if the voltage is made larger. As the cross-section of the conductor is determined by the value of the current, a conductor with reduced cross-section will suffice. The transmission system thus becomes more economical.

A typical transmission and distribution system is shown in Fig. 12.2.

Every factory has a separate establishment to look after the supply of electricity. It comprises of:

(i) the receiving station,

(ii) the distribution system, and

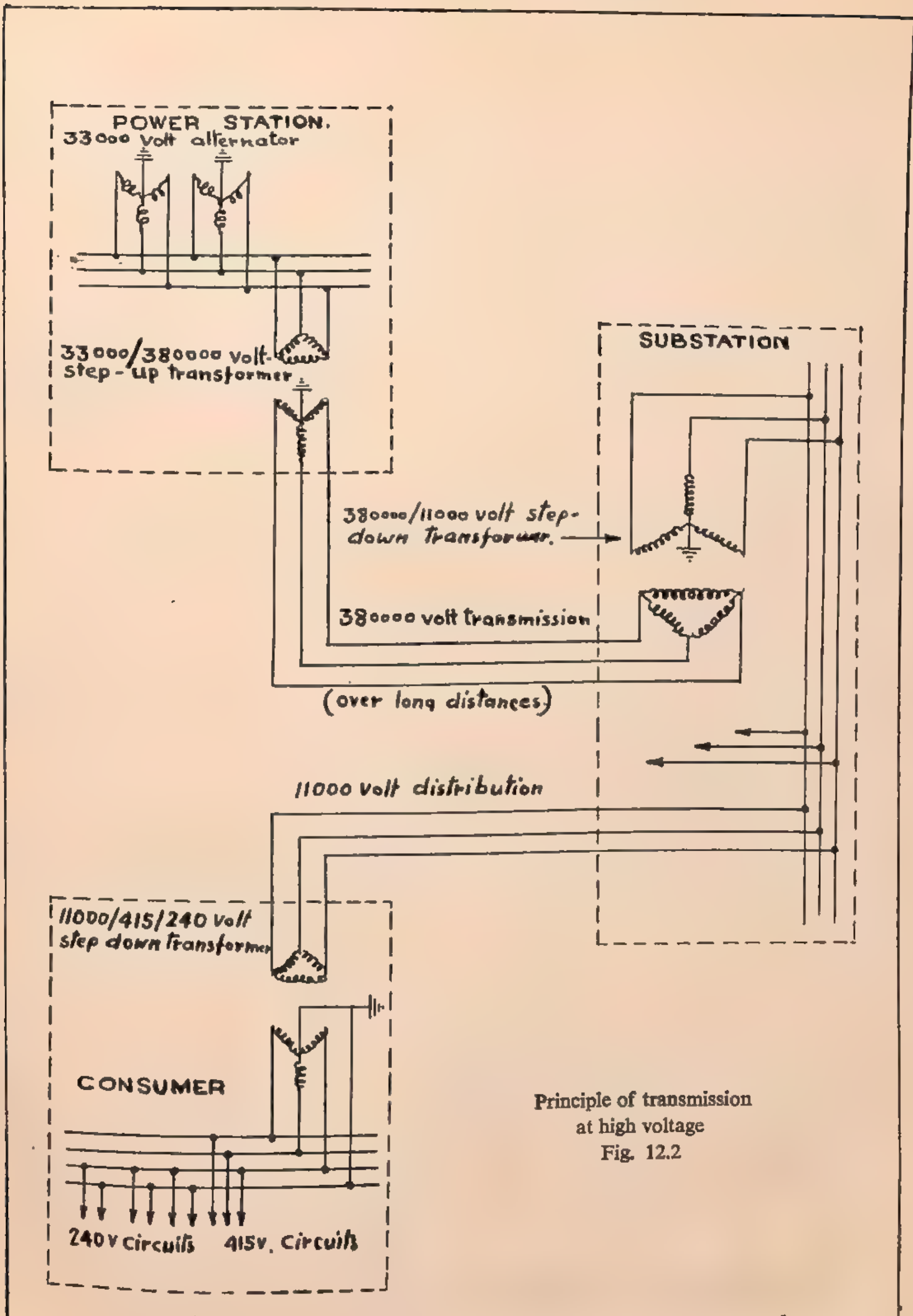
(iii) the consuming sections.

In the receiving station (called a sub-station), power is received at a high voltage (11,000 volts) and is stepped-down to 400 volts by means of a transformer, for connection to distribution net-work. The sub-station is provided with switch boards or distribution panels with suitable control switches for supply of power to different shops. The distribution panels have branches of supply lines leading to different shops and buildings. These panels are set up according to the power that is to be supplied for consumption.

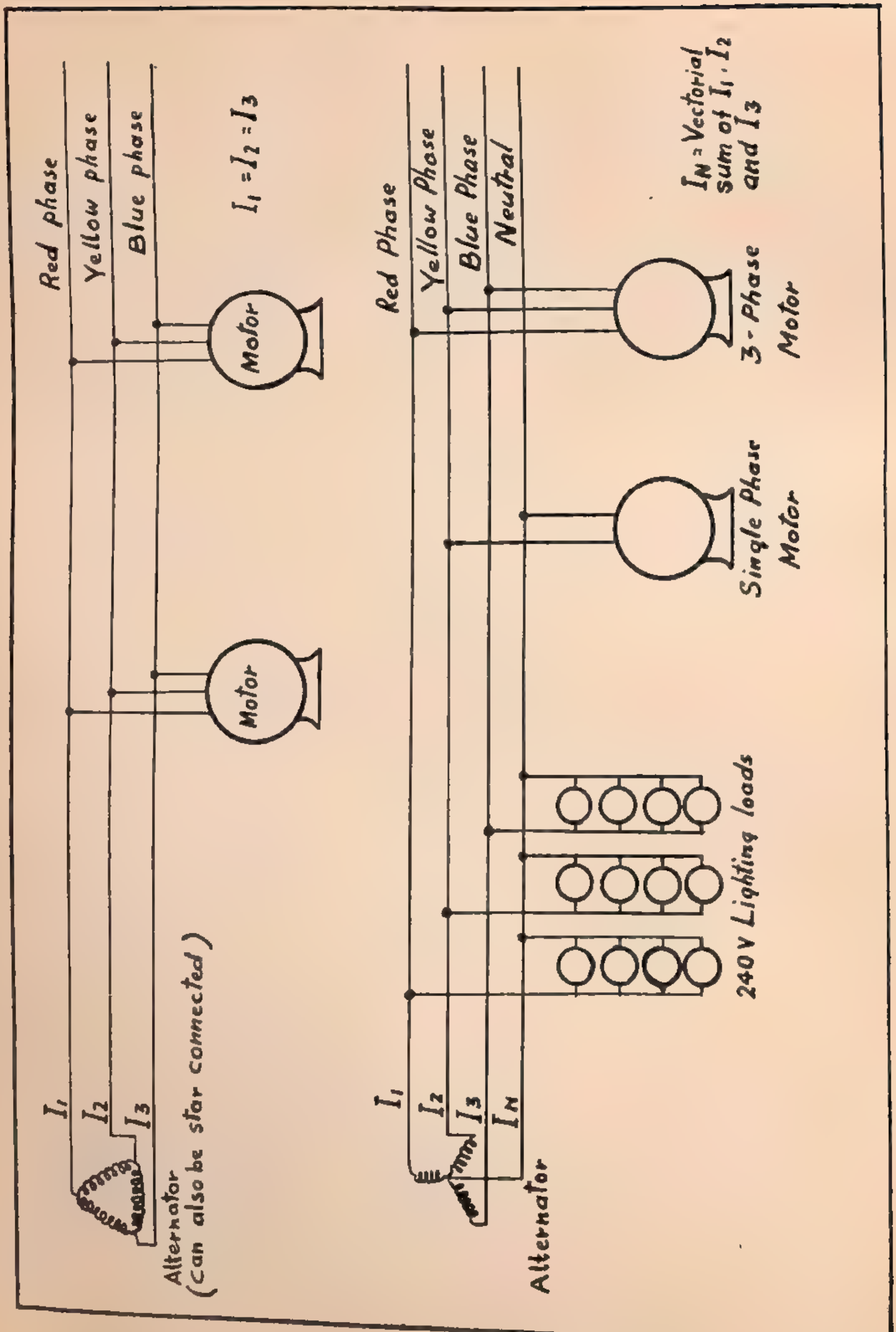
Switch boards are made up of a number of switches connected together with common *bus-bars*. In general they may be divided into three classes:

(1) Open type, (2) Metal-clad gears, (3) Cubical or truck gears.

All these types are provided with separate bus-bars for different phases of power supply and for neutral. These bus-bars are painted in red, green, black and white to indicate particular phases and neutral lines.



Principle of transmission
at high voltage
Fig. 12.2



Red phase
Yellow phase
Blue phase
$I_1 = I_2 = I_3$
Motor
Motor
I_1
I_2
I_3
Alternator
(Can also be star connected)
Red Phase
Yellow Phase
Blue Phase
Neutral
I_N = Vectorial sum of I_1, I_2 and I_3
3 - Phase Motor
Single Phase Motor
240 V Lighting loads
I_1
I_2
I_3
I_N
Alternator

Fig. 12.3

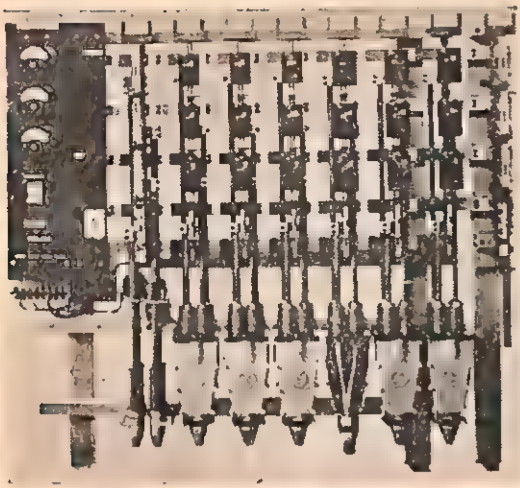


Fig. 12.4 Distribution system

Different out-going distributors are tapped from these bus-bars to supply power to individual shops as is shown in Figs. 12.2, 12.3 and 12.4.

The board is mounted with voltmeter, ammeter, kilowatt meter, circuit-brakers, fuse boxes, etc.

The details of a typical switch board may be seen in Fig. 12.5.

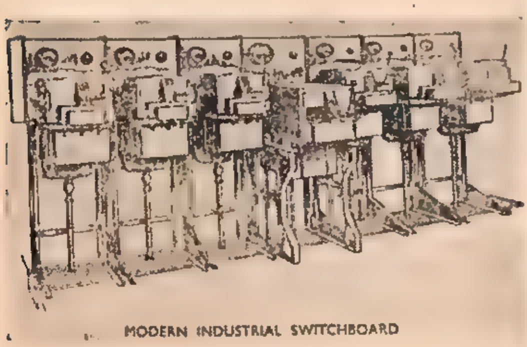


Fig. 12.5

The consuming section is energized through a net-work of electric lines from the main switch board of the particular shop. Branches are drawn from the main to individual points. The principle of distribution is shown in Fig. 12.6.

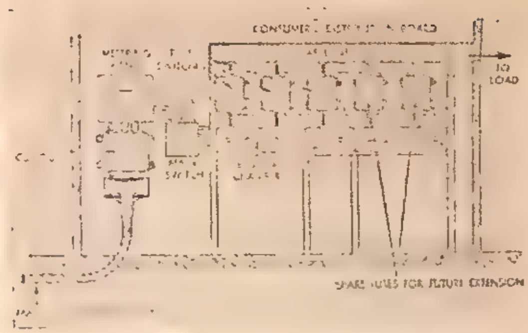


Fig. 12.6 Consumers' distribution board

Auxiliary switches are provided to start and stop each motor. Certain regulations are followed under the electricity supply rules for drawing electric wires from the supply source to the consuming points. Electrical fittings and parts are used to maintain continuous supply of electric power. Switch fuse boxes, insulated cables, junction boxes, double or triple pole iron clad switches, starters, electric motors, electric fans and lights are very common items in use.

The supplies may be either D.C. (direct current) or A.C. (alternating current). The distribution is in 2-wires and 3 or 4-wires system as it is a D.C. or an A.C. supply.

Power supply lines have 400 volts for electric motors and 230 volts for fans and lights.

To attend to the system of this supply, an electrical maintenance section is set up in every factory. They attend to the break-downs, replacement of the damaged and rectification of the faulty parts. They are equipped with a set of tools and instructions regarding the maintenance services. While at work, they are guided by some safety principles.

12.3 Common Electrician's Tools

The following portable tools and accessories are used for working on power

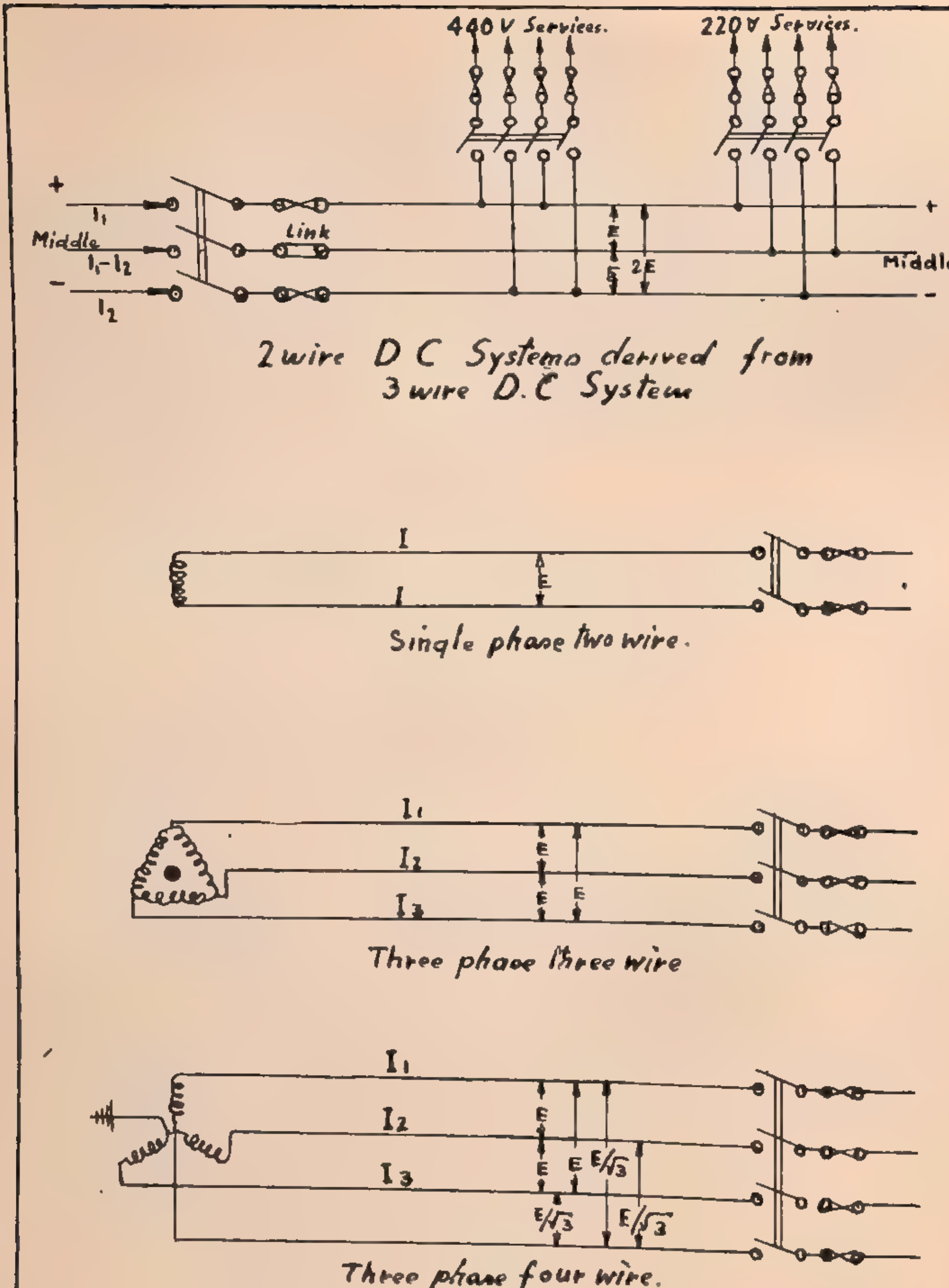


Fig. 12.7 Power distribution systems for A.C. and D.C. supplies

and lighting circuits:

1. Electrician's knife for skinning insulation from wires and for cutting insulating materials;
2. Flat-nose side-cutting pliers for gripping and forming insulation tubing and wires;
3. Side-cutting cutters for wire cutting;
4. Multi-purpose pliers with insulating handles for various wiring operations;
5. Round-nose pliers for loop terminating conductors;
6. Hacksaw for cutting cables and heavy-gauge bus-bars;
7. Screw-drivers (a set) with insulating handles;
8. Metal measuring rule;
9. Test lamp for checking circuits;
10. Set of files for filing work;
11. Electric soldering irons for tinning and soldering;
12. Blow torch for soldering heavy-gauge wire;
13. Portable transformer for welding and terminating wires;
14. Accessories for welding (goggles, electrode holders, heat-sink sets, protective shields, etc.);
15. Hollow drift and hammer for driving holes in brick walls;
16. Electric drill with set of bits;
17. Set of spanners;
18. Wiring marking-out aids;
19. Belt, climbers and ladder for top work;
20. Block and tackle with a set of grips for tensioning wires;
21. Roller device for straightening wires;
22. Hand tongs for compression and crimping connection of wires;
23. Portable hydraulic press for compression and crimping connection of wires;
24. Reel stand for unwiding wire coils;
25. Pneumatic hammer drill;
26. Electric drill;
27. Tongs for bending insulating tubing;
28. Voltage indicators;
29. A tool kit with standard carpenter's tool;
30. Conduit pipe benders; and
31. Conduit die set.

ELECTRICAL INSTRUMENTS IN USE

1. Avometer A.C. and D.C. with current range 0 to 100 amps. and voltage range 0 to 1000 volts. Resistance up to 40 megohms. Capacity .01 to 20 mfd.
2. Insulation tester 500 V-Megger.
3. Ammeter (Portable type) A.C. and D.C. 0 to 50 amps. or for higher range.
4. Voltmeter suitable for use on A.C. and D.C. range from 10 to 500 volts.
5. Watt-meter.
6. Kilowatt-hour meter.
7. Frequency meter (40 to 60 cps.)
8. Powerfactor meter.

MATERIALS NECESSARY FOR MAINTENANCE SERVICE

1. Insulating black tape.
2. Link clips.
3. Brass panel pin.
4. Fuse wires.
5. Cartridge fuse.
6. Earthening wire.
7. Flexible hose.
8. 1/2", 3/4", 1" teak wood battens.
9. Wooden corner pieces.
10. Wooden casing and caping.
11. Porcelain cleats.
12. Porcelain connectors.
13. Junction box.
14. Double board for switches.
15. Ceiling roses.
16. Lamp brackets.
17. Lamp holder bayanet cap.
18. Lamp holder screwed cap.
19. Adopters.
20. Electric bulb.
21. Flourescent tube light.

22. Conduit pipes.
23. Conduit pipe fittings (inspection type, viz. elbow, bend, tee, junction box, zig-zag and 4 way).
24. Electric cables of different quality and size, viz. P.V.C., T.R.S., V.I.R.
25. D.C.C. (Double cotton covered), S.C.C. (Silk cotton covered) wires.
26. Super enamelled wire of various gauges.
27. Pressphan sheet.
28. Egyptian cotton tape.
29. Leatheroid paper.
30. Mica sheet.
31. Quick air drying insulating varnish.
32. Electricians solder.
33. Empire sleeving.
34. Bakelite sheet.
35. Silk sleeving.

COMMON ELECTRICAL ACCESSORIES

These are:

1. Double pole iron clad switches (D.P.I.C.)
2. Triple pole iron clad switches (T.P.I.C.)
3. Tumbler switches (5 amp., 10 amp., 15 amp.)
4. Two-way switches.
5. Switch fuse box, etc.

12.4 Insulation

Insulation of live parts is important for reasons of safety of operators and consumers. The purpose of insulation is also to isolate an electrical conductor from another conductor and to prevent leakage of electric energy. This can be done by surrounding the wire with a complete covering of insulating material or by suspending it in air on suitably designed cleats, or hooks made of insulating materials such as porcelain or mica. Both of these systems are in common use for different kinds of electric circuits. An insulating material is considered to be a good one which will not allow any appreciable current to leak away from the conductor. When the current flows along a conductor at a high voltage the problem of insulation becomes more complex, because, at this stage, the current tends to puncture through the insulating material and promotes leakage. Special materials are selected for high tension (H.T.) insulation. These must work well against the effect of gas and temperature, stand against absorption of moisture. These should be tough and strong so that they may not rapture or crack under tension, compression or impact. Above all, these must have properties to offer resistance to leakage of current.

12.5 Classification of Insulation

Electrical insulation is classified according to the temperature up to which the material can be subjected. The five major classifications are given below:

Class O—includes cotton, silk or paper not immersed in insulating varnish.

Class A—includes cotton, silk or paper impregnated with varnish or enamel.

Class B—includes mica, fibre, glass or asbestos held together by means of an organic binder.

Class C—includes mica, glass or porcelain.

Class H—includes mica, fibre-glass or asbestos held together by means of a silicon substance as binder.

Maximum allowable temperatures for these classes of insulation are:

Class O	90°C
Class A	105°C
Class B	130°C
Class H	200°C
Class C	No limit selected.

12.6 Common Insulating Materials

Some of the most common materials used for insulation purposes are—Air (dry), Ebonite, Paraffin wax, Shellac, India rubber, Glass, Mica, Silk, Paper (dry), Porcelain, Slate, Marble, Cotton (dry), Pressphan paper, Teakwood (dry), Varnish. Of the above list, different insulating materials are used in different ways and methods. As for example, slate and marble are used for switch board panels; porcelain, steatite and glass for overhead line insulators, bushings or cleats; bitamen and paraffin wax as filling compounds for joint boxes; rubber and paper for cable manufacture; oil for transformer and circuit breakers; mica for insulation of machine parts; and cotton and silk as conductor coverings.

In addition to above, there are materials under the group (a) Thermoplastics and (b) Thermo-setting resins.

Under group (a), we have

(i) polythene in the form of sleeving and coverings of wires, sheets and rods;
(ii) Polystyrene as a bonding agent for cotton paper laminated sheet;
(iii) Polyvinyl-chloride (PVC) used as conductor covering in place of rubber; and
(iv) Aniline formaldehyde (Panilax) used for manufacturing boards and sheets.

Under group (b), the principal item is Pheno-formaldehyde (Bakelite). This material softens under heat, and can be molded, extruded or cast. It is used as a bonding agent for paper, fabric or wood-laminated products. Common articles of manufacture are tumbler switches, plugs and sockets, lamp holders, boxes for switch gears, etc.

Other insulating materials are better known by their trade names as indicated below:

Rigid sheets or boards:
- Sindanyo (Bitumen-asbestos boards)
- Permalin (Pheno-formaldehyde bonded wood)
- Paxolin (Pheno-formaldehyde bonded paper)
- Elephantide, Micatex (Press-board)
- Mycalex (Glass bonded mica)

Flexible sheets and tapes:
- Micanite (Mica splittings bonded on to cotton or silk)
- Leatheroid (Thin sheets or vulcanized fibre)
- Empire cloth and tape (Varnished cotton cloth).

Sleevings:
- Duratube, Micoflex (Extruded polyvinyl-chloride).

DRYING ELECTRICAL INSULATION

When varnish is used for insulation, the most favourite method of drying is by application of external heat. This is conveniently done in a baking oven. Some heating element is fitted in a reflector and is used for maintaining heat of the oven at a regulated temperature. Small and handy units can only be put inside the oven chamber. In case of big units improvised methods may be adopted. In practice, a tarpaulin is used to cover the unit with a few portable heaters placed inside. A vent at the top of the tarpaulin cover will allow moist air to escape. When insulation is dried and the unit is allowed to cool, the resistance increases to a high value.

TESTING OF INSULATION

Usually insulation is tested by an instrument called Megger. The instrument obtains its energy from a small hand-cranked generator. The unit to be tested is cut off from the power supply line. To test the insulation, one terminal of the Megger is connected to the winding and the other to the frame. Cranking the

Megger at a normal speed will cause the pointer of the instrument move over a scale which is graduated to indicate the value of insulation resistance.

The same instrument is used to check up the continuity of a coil of a motor or generator or of a circuit. If there is no break in the coil or in the circuit, the pointer will read zero when the instrument is operated. If there is any break, the pointer will move over the scale to the extent depending upon the amount of discontinuity in the circuit.

The Megger can be seen in Fig. 12.8.

Fig. 12.8 Megger

12.7 Electrical Appliances for Workshop Use

The following are a few of the many appliances used in the shops: (1) Electric motor, (2) Electric converter, (3) Storage cells or batteries, and (4) Transformers.

ELECTRIC MOTORS

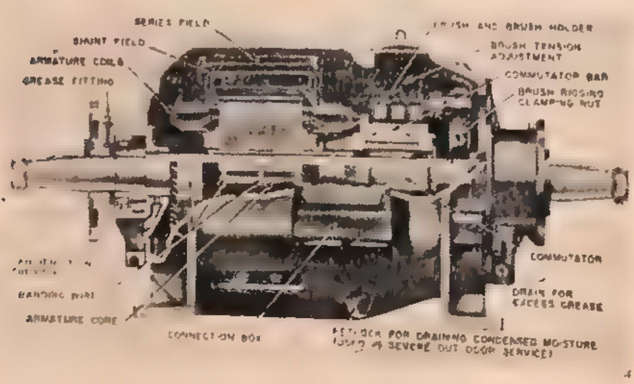
Motors may be either D.C. or A.C. motors. D.C. motors are distinguished from the A.C. variety by the *commutator* it has for distribution of current. There are three types of D.C. motors differentiated by their windings: series, shunt and compound. D.C. motors are bulky in size as compared to A.C. motors of the same horse power. General construction of a D.C. motor is shown in Fig. 12.9. In the drawing, the principal parts have been shown with names.

A.C. motors may vary from fractional horse power to 1000 H.P., according to need. They are of different types, both for the single-phase and for the 3-phase units.

Types of A.C. single-phase motors are: (i) shaded pole type, (ii) capacitor type, (iii) split phase type, and (iv) repulsion induction type.

Types of A.C. 3-phase motors are: (i) squirrel cage induction type, (ii) slip-

Fig. 12.9 D.C. Motor



ring induction, (iii) synchronous induction type, and (iv) commutator type for variable speed.

MAINTENANCE SERVICE OF MOTORS, ROUTINE INSPECTION AND REPAIR

The common failures in a motor are due to dampness and absorption of moisture. These cause the break-down of the insulation of windings. This is followed by short circuiting of the field or armature coils or earthing of the windings. The oil in the ring-bearings sometimes leaks along the shaft of the motor and drips on the commutator, and collects round the lower field coils. This oil film will cause sparking at the brushes which will burn the mica strips, separating the segments. It will also affect the rubber insulation of the connecting wires to the brushes and field coils. To keep the motors in their proper working condition, periodical attention is given to all of them in use.

The servicing is rendered as follows:

(i) The dirt or dust accumulated is blown off or drawn out by a portable blower or by a vaccum cleaner.

(ii) The insulation between the field and armature is tested. If found low, they are warmed up to improve. If the motor windings have become very damp or wet for not being used for a long time, the moisture should be absorbed by dry cloth as much as possible. A number of heaters should then be placed near the windings to complete the drying process. Current may also be fed into the windings at low voltage. The heat developed internally helps to drive off the moisture. It is essential to give the motor an insulation test before putting it back to use.

(iii) The bearings are cleaned. Grease applied earlier is removed as it may contain dust particles, and is replenished by fresh addition. If oil leakage results from the worn-out bearings, they should be changed by new ones.

(iv) Starter connections and mechanical fittings are examined for continuity and proper functioning.

(v) In addition to the above standard practices, particular attention should be given to sparking at the commutator. The motors should run almost free from sparking at the brushes at all loads. For this purpose the commutator should be first cleaned by a piece of clean folded rag. If rough, it should be carefully smoothed by a fine sand-paper without disturbing the hard skin formed on the surface of the copper segments. This hard skin prevents wear. The new carbon brush is to be dressed to match the curvature of the commutator with the help of sand-paper. If some mica strips are found raised, they should be scraped down slightly below the segments with a scraping tool made from a broken hacksaw blade.

Proper and regular maintenance reduces the number of failures due to normal wear and tear or any unforeseen reasons. In short, preventive maintenance of electrical equipment consists of:

(1) routine inspection,
(2) routine repairs, and
(3) general overhaul.

During the routine inspection the following action is to be taken:

1. Remove the fuses in the supply connection to prevent any accidental starting of the motor.
2. Check the motor fastenings.
3. Check for tight fit of pulley or drive gear and check on wear of gear teeth.
4. See that all the fastening bolts on end-shields are in place and are properly tightened.
5. Inspect the brush-lifting mechanism and see that all the brushes are simultaneously lowered on the slip rings.

6. Inspect the bearings, checking the level and grade of oil and the rotation of lubricating rings.

7. Inspect the accessible parts of the rotor winding, and see that the rotor does not rub against the stator core.

8. Inspect the end parts of the stator winding.

9. Check for good contact the supply cable connections.

10. Check the earthing connections.

11. Check the air gap with a gauge.

12. Clean the accessible parts of the motor.

During routine repairs, we are to work as follows:

1. Dismantle the motor.
2. Wipe the stator and rotor clean and blow out the ventilating ducts with compressed air.
3. Recoat the windings with varnish; if necessary, dry them out.
4. Wash the bearings and, if they are worn, replace them.
5. Assemble the motor.
6. Check the air gap.
7. In phase-wound motors, clean the slip rings and brush rigging, and fit the brushes.
8. Check the earthing.

For the purpose of general overhaul, the following action is to be taken.

1. Completely rewind the stator.
2. Completely rewind the rotor.
3. Replace the shaft.
4. Replace the bearings.
5. Replace the slip rings and brush-holders.

COMMON DEFECTS IN D.C. AND A.C. MOTORS

Troubles experienced in using the motors may be due to any one of the following causes.

(i) Operational difficulties arising out of trouble in the distribution system, failure of starters, blown fuses, reversed polarity of supply connection, failure of voltage, wrong connections of the terminals of the motor.

(ii) Field troubles arising out of short coils, grounded coils, open coils, reversed field pole, reversed interpole.

(iii) Armature troubles arising out of short and open armature coils, grounded armature coils and flash-over.

(iv) Motor-controller troubles.

For D.C. motors the common troubles are:

(1) *Starting troubles:* Sometimes the motor may refuse to start when the starter handle is operated. This may be due to (i) defective fuses, (ii) defective contact in the main switch and (iii) a broken resistance in the starter unit.

(2) *Overheating:* If the machine becomes hot while running, the cause may be (a) excessive external load, (b) excessive belt tension, (c) poor lubrication of bearing, (d) bent armature shaft or roughness of the commutator surface, (e) use of wrong grade of brushes, (f) defective field coil.

(3) *Sparking:* This may be due to (a) wrong brush position, (b) chattering of the brushes owing to poor fittings in holders, (c) bad contact with commutator owing to a tight fit of the brushes in the holders, (d) incorrect positioning of the brushes, (e) roughness of the commutator surface, and (f) an open or short circuited coil in the armature.

Sparks may also appear in the commutator, due to (a) excessive load, (b) a tight belt, (c) poor contact between brush and commutator, (d) insufficient brush pressure owing to weak spring, (e) accumulation of dust between commutator segments, (f) loose connection in the field coil, and (g) fault in armature winding.

(4) *Speed variation with load changes:* This may be due to wrong brush position. The speed, particularly of shunt wound

motors, falls when the load increases. In a series and compound wound motor the effect is reversed.

(5) *Motor rotating in wrong direction:* (i) To reverse the direction of rotation in a series wound motor the direction of field current or armature current is reversed. (Fig. 12.10).

(ii) In a shunt wound motor the current flow in the shunt winding or in armature has to be reversed. (Fig. 12.11).

(iii) In a compound wound motor the reversal is done by changing the flow of current in armature as well as in the inter-pole winding or in both shunt and field windings.

For A.C. Motors the common troubles are:

(1) *Starting troubles:* These may be caused by (a) insufficient voltage at the motor terminals owing to (i) excessive drop in the supply leads, (ii) partial or loose contact, (iii) blowing of fuses, and (iv) faulty connection in the starter;

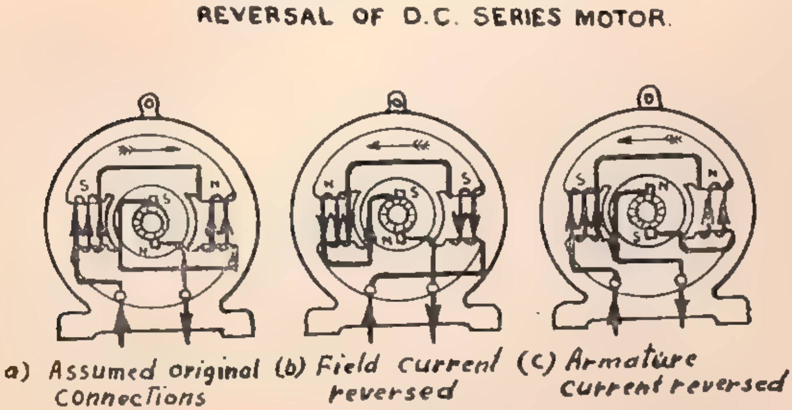


Fig. 12.10

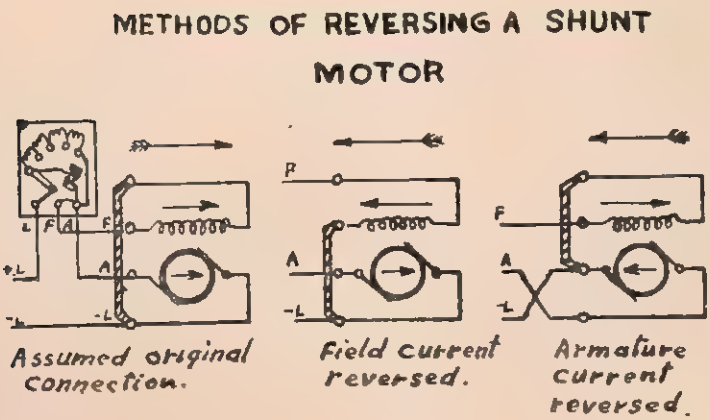


Fig. 12.11

(b) open circuit in the rotor; (c) defective brush contact; (d) broken resistance in the starter; (e) improper adjustment of overload coils in the starter; and (f) open circuit of stator winding.

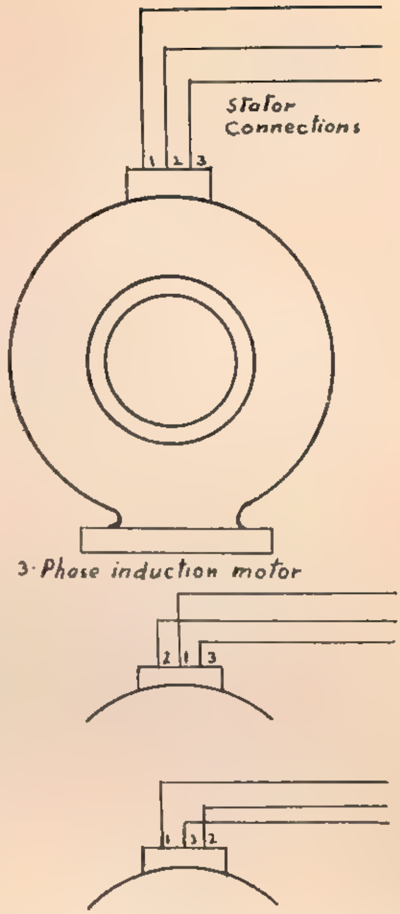
(2) *Failure to carry load:* In the case of an Induction motor, if the starter is kept in the start position, the motor will run on light load; but on full load the machine sometimes stops.

Owing to some mechanical defect in the starter, the handle may be in the run position leaving the contact in the starting position. If full load is put on to the motor, it will cause the machine to stall.

(3) *Overheating:* (a) the rotor may foul the stator when there are worn-out bearings. (b) An unbalanced voltage increases the total line current and causes the motor run unduly hot at full loads. (c) Single phasing occurs as a result of the disconnection between one of the three motor terminals and the supply. This may be due to the blowing out of the fuses in any one phase.

(4) *Abnormal speed variation with change of load:* If the resistances in the rotor circuit are not cut simultaneously in all the 3-phases in an induction motor, there will be a slip at full load.

(5) *Incorrect direction of rotation:* The motor may change direction of rotation if the phases are changed at the supply range. To rectify this, two of the three supply leads at the main switch or at the starter should be changed over. (Fig. 12.12)



Changing of rotation for 3 phase Motor

Fig. 12.12

SWITCH GEARS

Switch gears are made for different voltages and currents and are used for making and breaking the electric supplies in various ways. They are grouped as under:

(1) *Open type:* Knife switches, air circuit breakers, etc., are used on switch boards. Knife switches are designed for manual on-off switching of motors, generators and separate circuit sections. They may be single-pole, double-pole and triple-pole construction. They are designed for both front and rear connections of the wiring. In the first case, the contact terminals are located in the front of the panel and, in the second case, on the rear side.

Any disconnection of a live circuit is accompanied by an electric arc. The high temperature of the arc causes burning of the contacts. For high current, the units

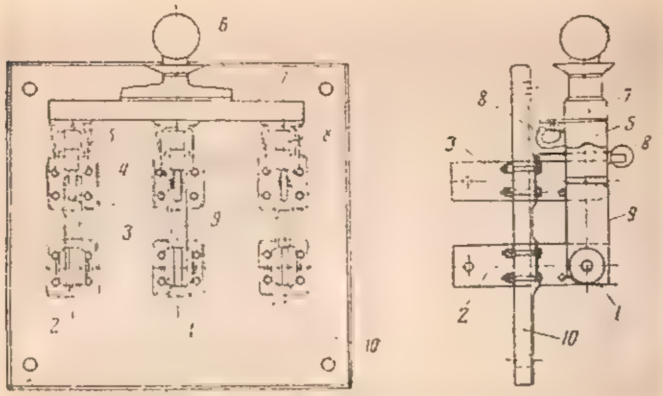


Fig. 12.13 Knife switch

are suitably modified to protect the main contacts from burning. A standard form of knife switch can be seen in Fig. 12.13.

(2) *Insulated:* This type is used in low voltage small domestic installations. In these units all current carrying parts are shrouded in insulating material.

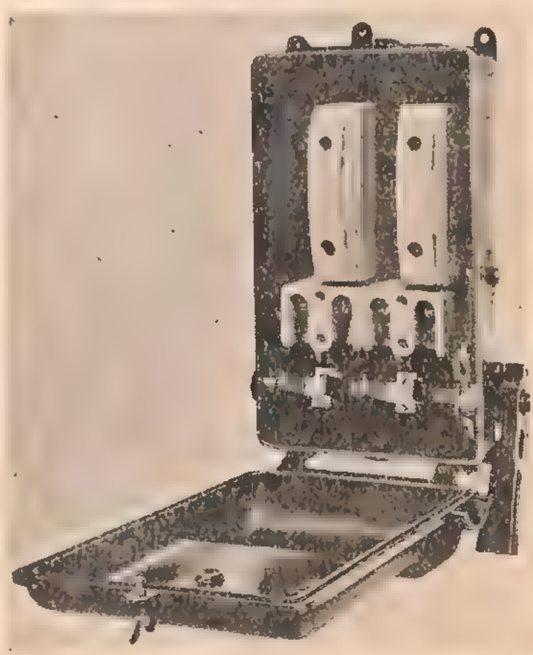
(3) *Lowtension iron clad:* This includes air and oil break switches and switch fuses of all types enclosed in iron casings. This is used extensively for installation work. In this type, all the individual components are enclosed in metal cases. They are usually floor-mounted on angle or cast iron frame work. Small units are suitable for wall-mounting. In an iron clad switch gear, the lid of the enclosure must be interlocked with the swtich operating handle. In this arrangement the lid cannot be opened unless the switch is in the OFF position. (Fig. 12.14.)

(4) *Skeleton type*: This comprises of open type fuses and switches, mounted on open iron frame-work. This type is economical. As the live part is not enclosed, this is suitable for use in sub-station switch rooms, where unauthorised persons are not allowed to enter.

(5) *High tension metal clad:* This is an oil filled circuit breaker mounted on pedestal. They are of two broad classes: indoor and outdoor types. Such types operate at voltages up to 275 KV. Suitable insulations are provided between live metals and earth. For high transmission voltage they may be as big as 10 ft. in height.

(6) *Cubical and truck type:* This is normally used for high voltage work in which the various components are enclosed in interlocked cubicals. In this, oil circuit

Fig. 12.14 Iron-clad switch gear



breakers are generally used by isolating the breaker from the live bus-bars. Cubical units are also made of the truck type, whereby the circuit breaker with all inter-connections can be withdrawn as a whole from the live bus-bars for inspection and cleaning purposes.

(7) *Cellular type:* This is used for high voltage work. This type is generally employed in generating stations for control of high voltages. Switch boards are encased in cells which are kept under lock and key and are operated by responsible persons only.

MOTOR STARTERS AND CONTROLLERS

In addition to the above seven types of switches, there are various types of motor starters for different types of electric motors to control their operations at starting. This is necessary because the resistance of the armature is very small and if the full supply pressure is applied to the machine at rest, heavy current will flow and cause not only voltage drop at the supply mains but serious damage to the windings. For this reason, a resistance is first inserted in the circuit which limits the current flow until the machine has developed a back EMF by its rotation. This resistance is arranged in steps, which are controlled by means of a stud switch. The resistance is gradually cut out as the motor gains speed. The controlling handle of this switch is held in full ON position by a small electro-magnet. When there is no load, the electro-magnet stops functioning and the handle is pulled back to OFF position by the action of a spring attached to the handle. In the case of a D.C. motor, the principle of the starter is shown in Fig. 12.15.

In the case of A.C. motors, starters are designed differently to suit various classes of motors, viz., Synchronous motors, Induction motors and Commutator motors, and the conditions under which the motor has to start.

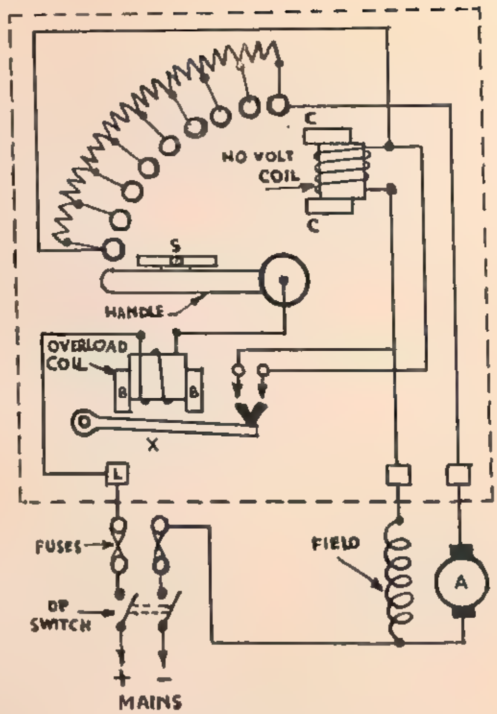


Fig. 12.15 Connection of a starter for a shunt or compound motor

The working principles and the connections of some of the starters may be seen in Figs. 12.16, 12.17, 12.18 and 12.19.

Types of Starters

(1) Rheostatic starters (which insert a variable resistance in series with the motor) may be classified as below :

(i) *Face-plate starter,* (ii) *Drum starter :* In these, the contacts are on a cylindrical surface. (iii) *Multiple switch starter :* In this, the resistances are controlled by separate and suitably interlocked switches. (iv) *Solenoid operated starters controlled by a start and stop pushed button :* In this type, the lever of a face-plate starter is moved by means of solenoid and core. (v) *Liquid starters* may be automatic or

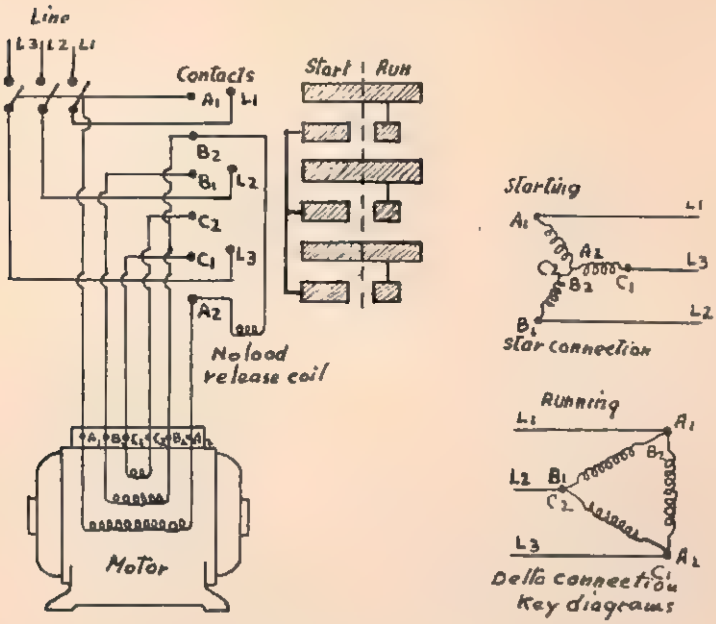
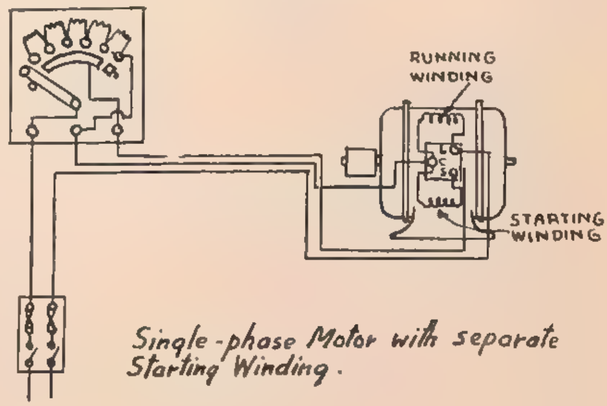


Fig. 12.16 Star-delta starter for three-phase induction motor



When the last stud of the starting switch is reached, the starting winding is disconnected from the supply.

Fig. 12.17

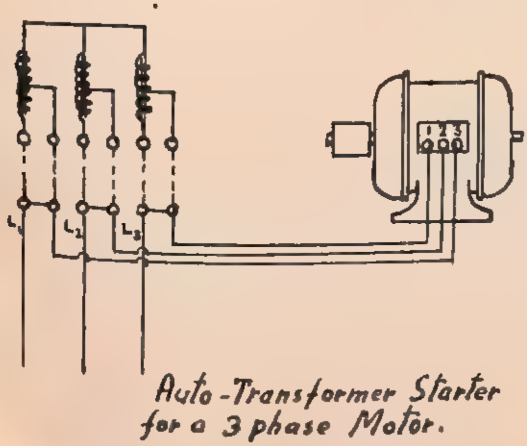


Fig. 12.18

The dotted lines show starting position of the starter contacts. In this position a portion of line voltage only is applied to the motor windings. When the machine has gained speed the starter is switched over to the running position shown with full lines. The full voltage is then available to the three terminals.

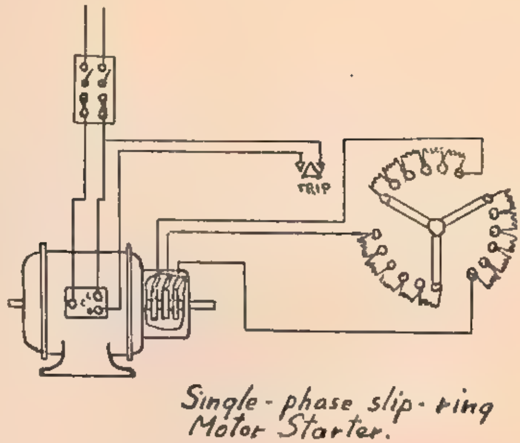


Fig. 12.19

A trip switch is interlocked with this for the purpose of cutting out the starting winding when the machine has run up to speed.

manual operated. These are generally used up to 1000 HP motors. In this, the area of contact between the electrodes and a suitable electrolyte is varied either by raising and lowering the electrodes or by varying the level of the electrolyte.

(2) The compensator starter for 2-phase and 3-phase AC motors consists of an auto-transformer and switch so arranged that, when the switch is thrown into an intermediate position, reduced voltage is applied to the motor by the auto-transformer. They may be of air break or oil break type, used for motors from 50 HP to 250 HP.

(3) Star-delta starter for polyphase induction motors are connected in Star during the starting period and Delta for normal running. They may be air break type or oil immersed types, used for motors from 7.5 HP to 25 HP.

ELECTRIC CONVERTERS

Where the power supply is A.C. but D.C. supply is necessary, some type of converter is necessary. There are four types of converters available. They are :

(1) Metal rectifier, (2) Mercury bulb rectifier, (3) Motor generator set, and (4) Rotary converter.

1. *Metal rectifiers* are static. Their function depends on the fact that certain elements allow an easy flow of current in one direction, but resists the flow in the opposite direction. Metal rectifiers are made of plates coated with semi-conductor, viz., copper-oxides or selenium.

2. *Mercury arc rectifier :* (a) They may be of thermionic or mercury arc types. The thermionic unit consists of an evacuated bulb with a metal filament inside and an anode or plate. When the filament is heated it emits electrons which are collected at the metal anode whenever the anode is at a higher potential. The flow of current is unidirectional.

(b) The mercury arc rectifier is a similar device except that the bulb contains a small quantity of mercury vapour and a heated spot in a pool of mercury (Fig. 12.20).

3. *Motor generator set :* In motor generator set, an A.C. motor is directly coupled with a D.C. generator. While the motor is run from A.C. supply, D.C. supply is delivered through the commutator of the generator.

4. *Rotary converter :* The unit consists of a rotating armature, with slip rings at one end and a commutator at the other. Alternating current is supplied to the slip

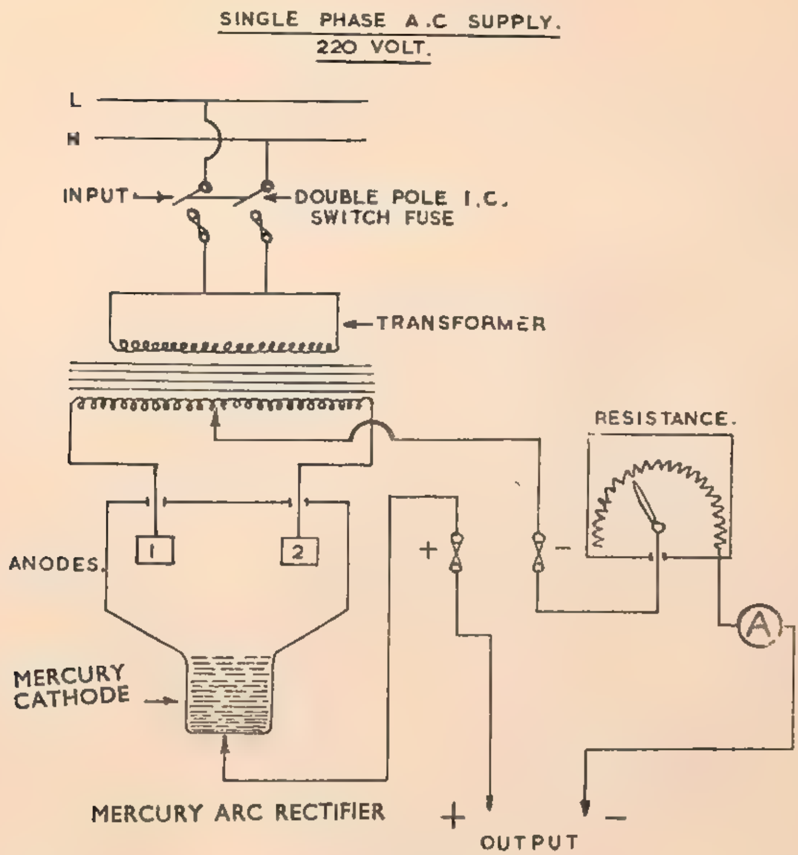


Fig. 12.20

rings to run the armature as a motor. The opposite ends of the coils are connected with the segments of a commutator. The field is excited from the D.C. end of the armature itself.

12.8 Storage Cells—Batteries and Battery Circuits

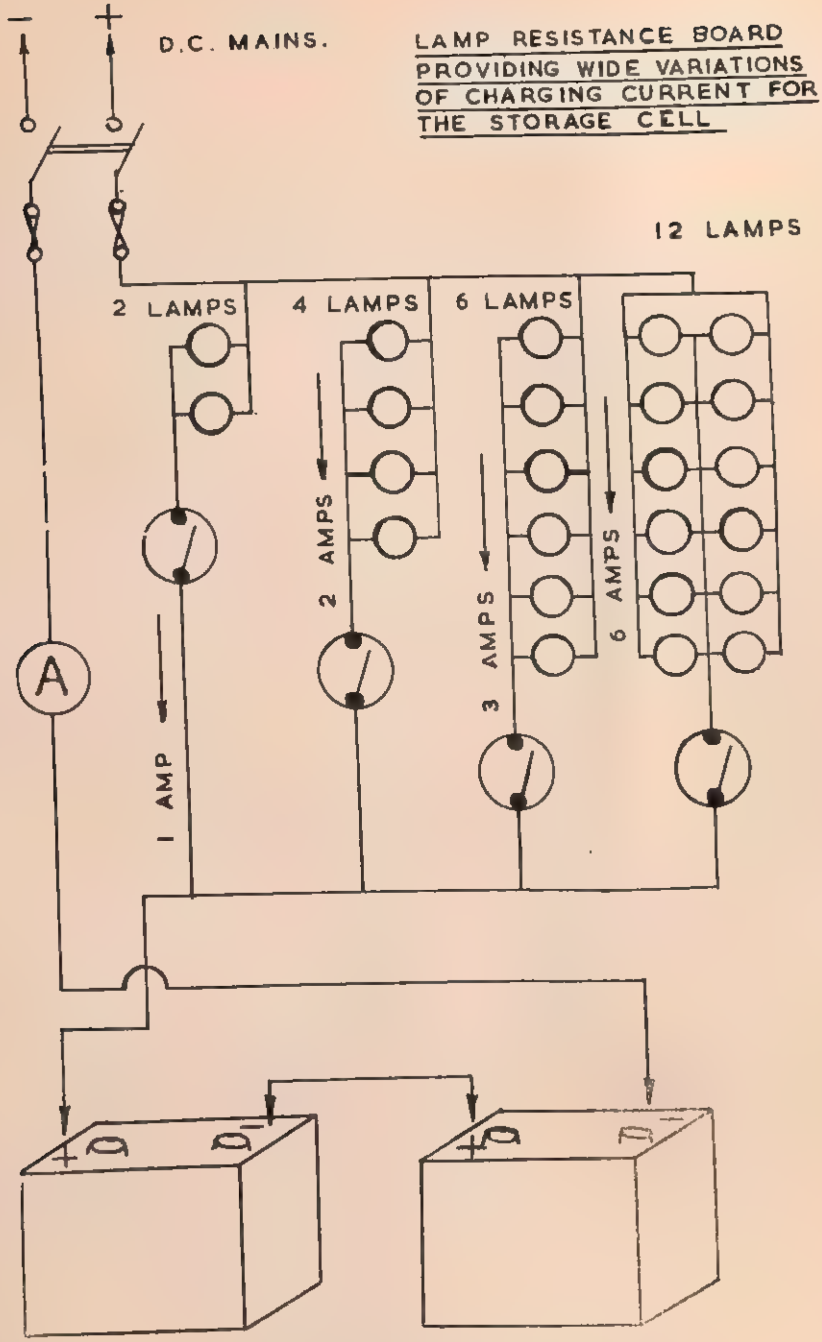
There are two main types of cells that produce electricity by chemical action : One is the primary cell and the other is the secondary cell.

THE PRIMARY CELL

A simple primary cell forms the first practical method of producing an electric current. All primary cells have a liquid or paste as electrolyte with two electrodes of two different metals inserted in it. A chemical action starts between these elements and when the terminals of the plates are joined, a current flows. This has limited life and is discorded when the electrolyte becomes exhausted. This is condemned because the cells cannot be changed or the component parts cannot be renewed. The voltage in a unit is 1.5 volts, which is increased by putting them in series as in the case of torch lights.

THE ACCUMULATOR

This is a wet cell. In dry condition it comprises a container with a grid of



BOTH BATTERIES PUT ON CHARGE

Fig. 12.21

specially prepared positive plates filled with paste of red lead Pb_3O_4 and negative plates made of litherge (PbO). These are placed in position and the container is sealed at the top leaving a passage for pouring electrolyte in the container. Sulphuric acid of sp-gr 1.250 is used as electrolyte in acid batteries and caustic potash solution for alkaline batteries. At this stage the batteries are charged by passing D.C. current through the electrolyte at a low voltage of 6 to 8 volts for 6-volt batteries and 12 to 16 volts for 12-volt batteries at a very slow rate of current between 1 to 6 amperes or as recommended by the manufacturer, by means of a battery charging set. The arrangement is shown in Fig. 12.21. Any number of cells can be charged in series since the same current will flow through each.

When mixing fresh electrolyte, always add the acid slowly to the water, stirring it all the time. Care should be taken while mixing the acid with distilled water as high heat is generated while concentrated acid comes in contact with water.

Effects of Charge

The effects are :

(a) The positive plates become rich chocolate brown in colour.

(b) The negative plates become metallic grey in colour.

(c) The density of electrolyte increases.

(d) Free gassing at the plates results when the chemical action is completed.

Effects of Discharge

These are : (i) Both sets of plates become similar in colour. (ii) The density of the electrolyte decreases. The process of charging changes the chemical composition of both the positive and negative plates. When charged, the unit will be ready to discharge, i.e., generate current by a reverse chemical action. The cycle of operation may be repeated and the units used over and again until the plates are damaged. Here lies the advantage of the wet cell batteries. Once exhausted, i.e., completely discharged, they can be recharged for making them serviceable again. The condition of charge or discharge of a battery may be determined by *hydrometer* readings of the electrolyte. For this test the filler cap of the battery is removed and enough electrolyte is drawn into a glass barrel to make the hydrometer float. Thus the sp. gr. of the electrolyte is recorded. For a charged lead acid battery the sp.gr. of the electrolyte should be above 1.250 at 80°F. At temperatures higher than 80°F, it should be more as corrected for the particular temperature. The normal voltage of any lead acid cell is 2 volts. When tested in full charged condition, it will show 2.6 volts which will drop to 2.2 volts when taken off the charge. During the process of discharge while in use it will fall gradually to 2.0 volts and finally to 1.8 volts. The cell must not be exhausted beyond this limit or else it will be ruined. A fully charged alkaline battery will have a voltage of about 1.35 volts per cell at normal charge or discharge current but when exhausted the voltage will fall down to 1.1 volts per cell.

Capacity of Cells

The capacity of a cell is measured in ampere hours and is the product of number of amperes it will give and the number of hours for which current can be taken. Accumulators are generally connected in series. A number of cells so connected

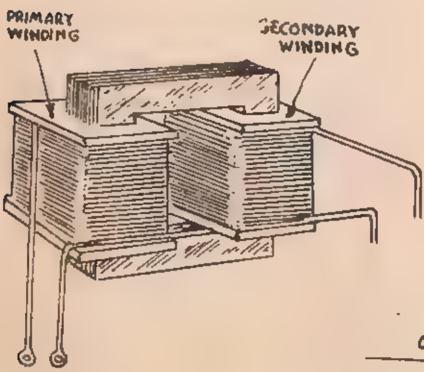
are called battery. Normally these batteries are used for supplying currents at 6 volts and 12 volts for use in shops. They are manufactured as such. From a battery a supply of current can be taken as a small current for a large number of hours or a large current for a small number of hours. The limitation is that the safe discharge rate recommended by the maker must not be exceeded. Usually batteries are manufactured with capacities of 60, 100 and 300 ampere hours, having different sizes and number of plates.

Principal Faults

Some of the principal faults that may occur are :

(1) Buckling of plates resulting in internal short circuit.
(2) A deposit of sediment, due to active material dropping away from the plates and resulting in loss of capacity. The sediment may short circuit the bottom of the plates.
(3) Sulphating of plates due to discharge to a point when the voltage drops below 1.8 volts.

Fig. 12.22 Transformer winding



Main Uses of Accumulators

Stationary batteries are employed for telegraphic and telephone systems, emergency lighting. Portable units are used for radios, traction, motor cars, etc. In many public buildings, theatres, cinemas, hospitals, ships, there are independent systems of lighting for the use in the event of failure of the main supply. Batteries are installed with control gears for automatic change over of the load on failure of the main supply. For voltage higher than 6 volts and 12 volts, large number of batteries are used with series and parallel connections for the required voltage and current output.

In both the categories of batteries a few varieties are :

1. Dry cell, 2. Daniel cell,
3. Edison cell, 4. Leclanche cell,
5. NiFe cell.

TRANSFORMERS

Like electric motor, transformer is one of the most important electrical appliances. It helps in increasing or decreasing the voltage to a great ratio. It is therefore an indispensable unit for transmission and distribution of electric power. The unit which receives power at a low voltage but delivers power at a higher voltages is called a *step-up* transformer, but which receives power at a high voltage and supplies it at a low voltage is called a *step-down* transformer.

The principle of work is explained in Fig. 12.23, and a practical form in Fig. 12.22.

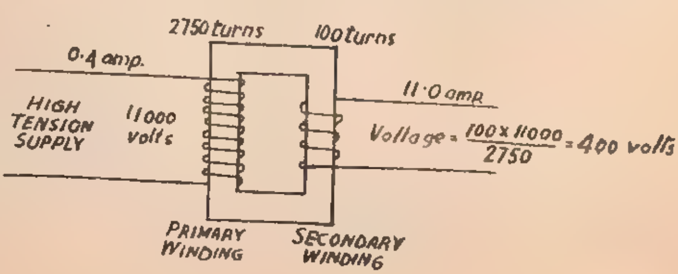


Fig. 12.23 Principle of transformer

In case of a transformer the values of the current and of the voltage in primary and secondary circuits can be obtained from the simple relations :

$$I_p T_p = I_s T_r \qquad \ldots\ldots(1)$$

$$\frac{I_p}{I_s} = \frac{T_s}{T_p} \qquad \ldots\ldots(2)$$

$$\frac{E_p}{E_s} = \frac{T_p}{T_s} \qquad \ldots\ldots(3)$$

$$E_s I_s = E_p I_p \qquad \ldots\ldots(4)$$

Where,

T_p = the number of primary turns,
T_s = the number of secondary turns,
I_p = the current in the primary coil,
I_s = the current in the secondary coil,
E_p = the primary voltage,
E_s = the secondary voltage.

It will be seen from the above that practically any voltage required can be obtained from such a transformer by having an appropriate ratio of turns of the secondary and primary coils.

It is easy to understand now that in the step-up transformer the number of turns in the secondary coil is more than that in the primary and in the step-down transformer it is the other way round.

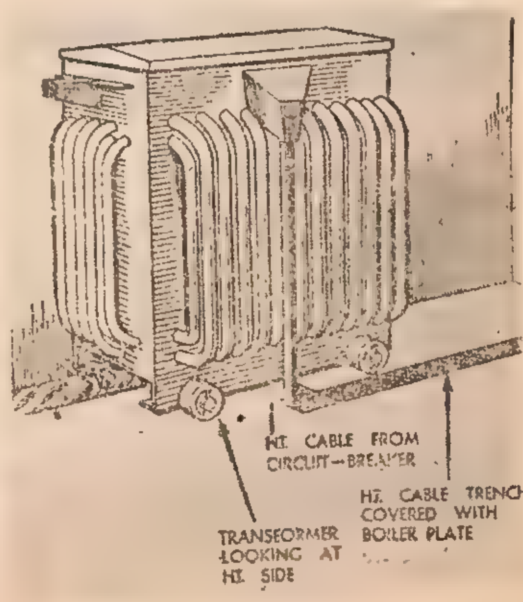
In the step-down type, transformers are available in different capacities, viz., 50 KVA, 250 KVA, 500 KVA and 1000 KVA for supply of power to workshops and for domestic consumption.

The core of the transformer comprising the primary coil and secondary coil is kept suspended inside a metallic container. The terminals of the transformer are so arranged that all the H.T. connections are on one side and the L.T. connections on the other. Copper risers are fitted to connect the ends of the winding to the terminals. These are held in hard wood cleats and are enclosed in Bakelite tubes. In practice, adjustments for small increase or decrease in voltage are necessary for varying load conditions. The adjustments are effected by bringing out tapping from the primary or secondary windings. The tappings are usually taken from H.T. windings allowing a maximum of 5% variation of the normal voltage.

During the flow of the current, heat is generated in the coil and also in the core. It is, therefore, necessary to keep the core submerged in a bath of oil to carry away some of the heat. The rectangular tank is fitted with a number of circulating tubes on all four sides. These give the unit a characteristic appearance. While the hot oil inside the tank rises towards the top, the cold oil in these tubes gets at the bottom. The hot oil passes through these and gets cooled due to contact with air arround them. A transformer in use is shown in Fig. 12.24.

With the wound core and oil in position, it is necessary to seal the unit to prevent any absorption of moisture by the oil. The oil must be free from any traces of moisture. Otherwise, the unit will be damaged.

Fig. 12.24



Before using, the oil is preheated for the purpose of *dehydrating*, i.e., removing the moisture. It is also tested for its *dielectric* strength for about 22,000 volts and then used in the transformer. This means that the oil will not allow a spark to jump between two terminal knobs which are charged at 22,000 volts. To attain that value, the oil is treated by a dehydrating machine. This machine has a circulating pump and a heating coil arround an evaporator through which the oil is pumped. During the process the oil is drawn from the tank and delivered back to the tank after treatment. In doing so the pump is connected with the tank direct by means of metallic tubes for circulation of this oil. The processing is continuously done for several hours. Samples of oil are taken from the tank periodically till satisfactory test result is obtained. Such treatment is not usually necessary for transformer in use except when the oil is refilled partially or fully.

Maintenance of Transformers

Transformer requires less attention than most other electrical apparatus. Some maintenance is however necessary. The temperature, load conditions and insulation resistance should be checked periodically and recorded.

Inspection of the windings and core should be made once a year. The cover should be removed and inspection conducted for accumulation of dirt, corrosion, loose connections, discolouration caused by excessive heat. The windings may be cleaned with a vaccum cleaner or by dry compressed air. All insulating surfaces should be wiped clean with dry cloth.

In the oil-filled transformer, if heavy accumulation of *sludge* is noticed, the oil is drained off, the inside of the tank and the core with windings are washed with clean oil. The old oil is filtered, treated and returned to the tank through the filter after testing its dielectric strength.

12.9 Electric Wiring

The primary object of any system of wiring is to distribute safely the electrical energy to the various points at which it is required through conductors. Such conductors are primarily available in the forms of wire, cable, bus-bar, etc.

Wire is a bare or insulated conductor consisting of one or several smaller strands used for transmission or distribution of electric power.

Bare unprotected wire has no insulating or protecting sheathings.

Insulated wire has conductors or cores covered with an insulating sheathing.

Unprotected insulated wire is a wire the insulation of which is not protected with special sheathings from mechanical damage.

Protected insulated wire is a wire enclosed in a metal or any other mechanically strong sheathing.

Core is one or more twisted strands of wire used as conductor of electric current.

Multi-core wire is a wire with several cores insulated from each other and enclosed in a common sheathing.

Cord is a wire consisting of two or more twisted insulated cores, having considerable flexibility.

Cable is one or several single or multi-strand insulated wires enclosed in a continuous protective sheath of metal viz., lead or aluminium.

In electrical wiring the following points should be considered :

(1) *Electrical safety :* This is the most important point and under no circumstances must there be any leakage or danger of electric shock to persons using the supply.

(2) *Mechanical Immunity :* The wiring must be protected from damage during the time of decoration of the walls or for final wood working. The layout of the wiring should be so planned that any interference with subsequent work on the building is avoided.

(3) *Permanence :* The wiring must not deteriorate under the action of weather, fumes, dampness, etc.

(4) *Appearance :* For certain work, appearance or invisibility is important. Domestic wiring may be concealed or exposed. In the latter case, the wiring should be arranged in a neat layout and finish. In factories, appearance is not so very important but the work should be neat.

CABLE CLASSIFICATION

Cables for house wiring purposes are classified according to the type of insulation of the core.

Taped and Braided VIR Cable

This is a standard form of cable, insulated with vulcanised India-rubber. It is then covered with tape and finally finished with a braiding of cotton and dipped in coloured wax to protect it from damp. The colours are red and black.

Lead Covered VIR Cable

In this variety, the cable is covered with a layer of lead in place of waxed braiding. The protective coat is mechanically strong and is ductile enough for bending during wiring. This type of cable is much more expensive than other varieties.

Tough-rubber-sheathed Cable

The general term applied to this class of cable is TRS. In this cable, the rubber insulation is very thick and sufficiently hard for protection. For this variety CTS is the registered trade name of the manufacturer. CTS stands for Cab Tyre Sheathed.

PVC (Poly-Vinyl-Chloride) Cable

PVC is plastic synthetic resin which is flexible, waterproof and unaffected by oil or petrol. The insulation quality of this material is lower than that of rubber. The thickness of insulation, therefore, is made slightly greater than that of the VIR cable.

Lead Covered Paper Insulated Cable

This class of cable is used for long runs and for *rising mains* in multifloor residential buildings.

Flexibles

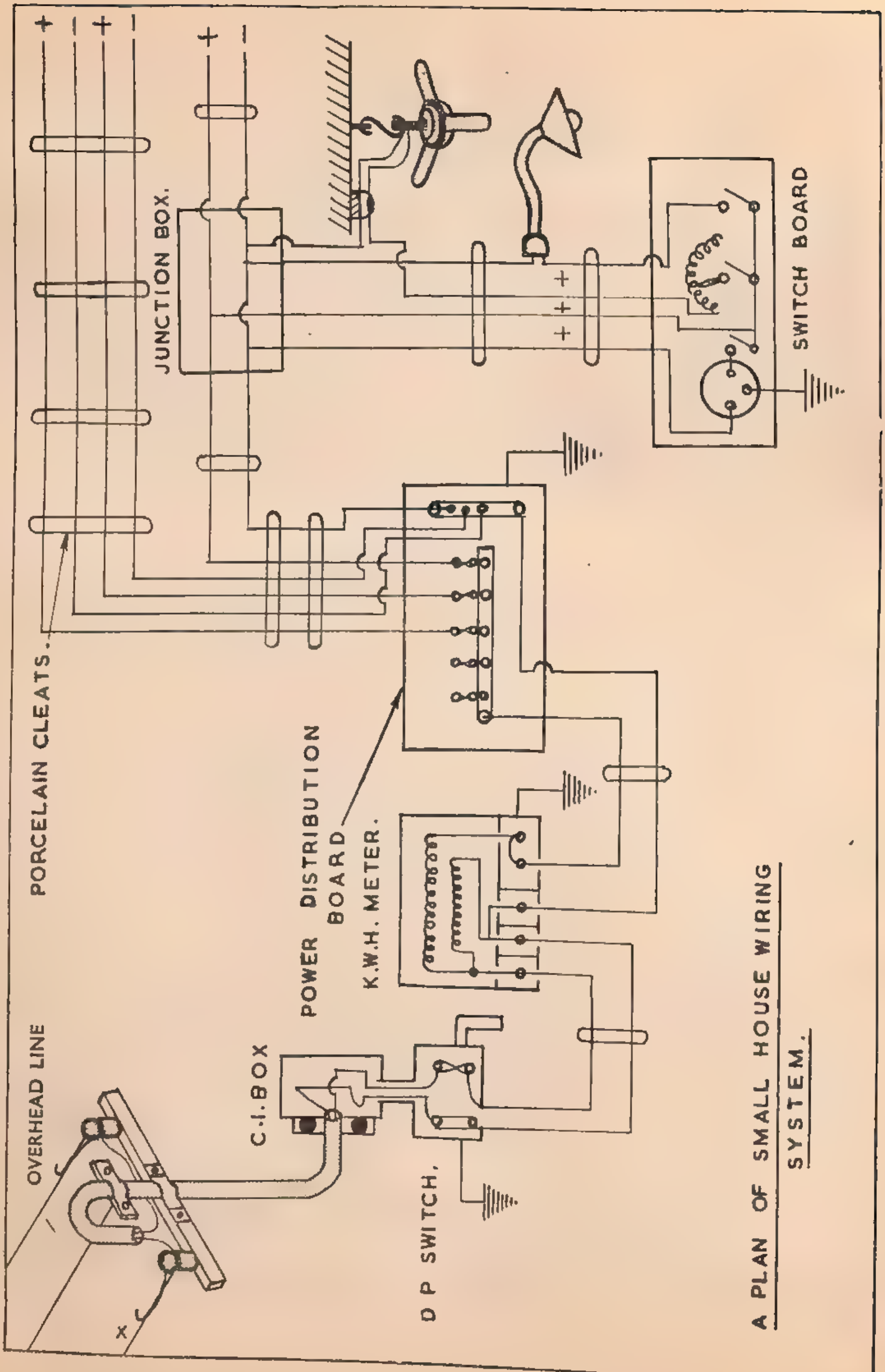
This is used for pendants only and not for wiring purposes. The switch should be so placed that the 'flex' is dead when the apparatus connected by it is not in use.

CURRENT RATING FOR WIRE CABLES

The current carrying capacities of cables of different size can be obtained from the following table :

Size	*Current rating*	*Remarks*
1/0.044	5 amp	
3/0.029	5 "	The cables may be of
3/0.036	10 "	single core, twin cores
7/0.029	15 "	and three cores.
7/0.036	24 "	The size 3/0.029 signi-
7/0.044	31 "	fies three strands of
7/0.052	37 "	wire each of diameter
		0.029 inches (0.74mm)

N.B. Due to the introduction of the C.G.S. system of measurement, new specification for different sizes of cables is being adopted, in practice under recommendation of Indian Standards Institution.



A PLAN OF SMALL HOUSE WIRING SYSTEM.
SWITCH BOARD
JUNCTION BOX.
PORCELAIN CLEATS.
POWER DISTRIBUTION BOARD
K.W.H. METER.
C.I. BOX
OVERHEAD LINE
D P SWITCH.

Fig. 12.25

12.10 Types of Wiring

The various types of wiring for domestic supplies are :

(1) Procelain cleat wiring (for short-term purpose)
(2) C.T.S. wiring
(3) Lead cable wiring
(4) Wood casing wiring
(5) Conduit pipe wiring
(6) G.I. flexible pipe wiring
(7) Concealed wiring

Some of these types are also used for industrial power supplies and lighting circuits.

A circuit diagram of two points is shown in Fig. 12.25. This explains the general principle of connecting various points. The cable size and other accessories are selected in accordance with the amperes consumed by the points in the circuit. The switches and fuses are put on the live line of the circuit so that in its off position, the wire beyond the switch is dead and is not subjected to any heating effect from the current flowing through the line. An example of joining

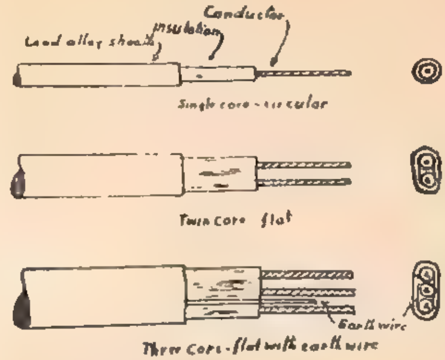


Fig. 12.27

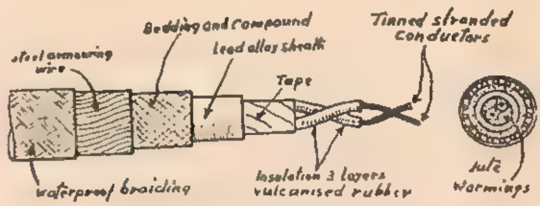


Fig. 12.28

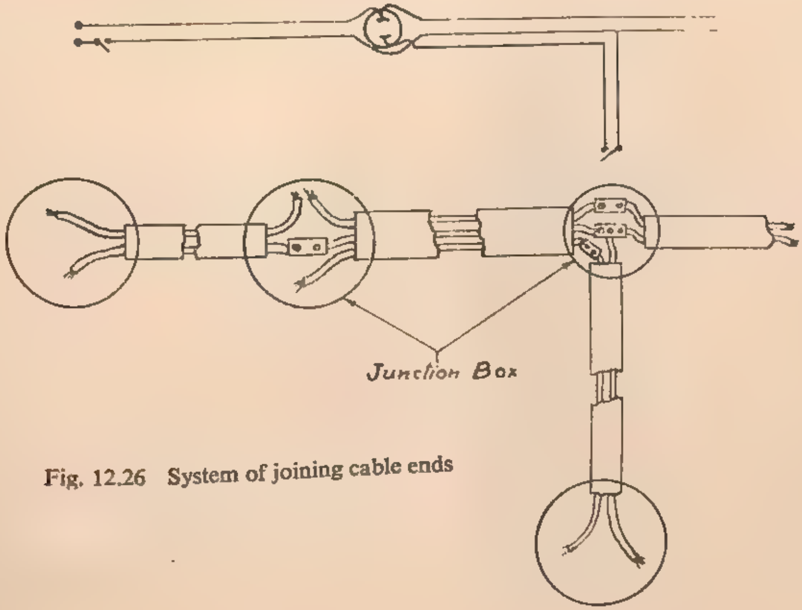


Fig. 12.26 System of joining cable ends

the cable ends in junction boxes may be seen in Fig. 12.26.

Cables may be of single core, twin cores and three cores. Single core cables are circular in shape but the twin core and three core units are flat. These may be seen with the different layers of insulations in Figs. 12.27 and 12.28.

CABLE JOINTS AND SPLICINGS

In electrical wiring, jointing of conductor is normally carried out in a *connector*. Nevertheless, it is sometimes necessary to use joint when repairing an old installation or in case of temporary wiring, although it should be carried out as a last resort.

Jointing conductor is the most exacting of all electrical jobs and it requires great skill. Great care is necessary to make a joint perfect and with proper insulation.

The practical details and the correct method of making a few joints are explained below.

Running Joint on Single Conductor

The insulation is cut about 100 mm. by using a sharp knife. The first step in making a joint in a single conductor is shown in Fig. 12.29(a). The brading and tape is bent backward and cut off neatly. About 35 mm. of insulating rubber should be exposed after the brading is cut off as shown in Fig. 12.29(b).

(a)

(b)

Fig. 12.29

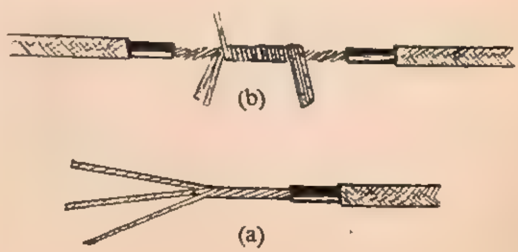
(a) Fig. 12.30 (b)

The exposed wire should be cleaned. It should be wiped with a clean rag. The surface tinning of the conductors must not be scraped.

The copper parts are laid together and twisted three to four times until they hold securely as shown in 12.30 (a). Then each end is taken separately and the joint finished neatly by making six turns around the main conductor. The waste end piece, if any, left is cut off. The sharpness of any end of wire is to be smoothened by a smooth file.

The joint must now be soldered, care being taken that the conductors do not get overheated to damage the rubber insulation near the joint. Over the joint, the insulation is built up firstly by applying a coat of rubber solution to fix up a layer of rubber strip tape. The joint is then

Figs. 12.31 (a), (b)



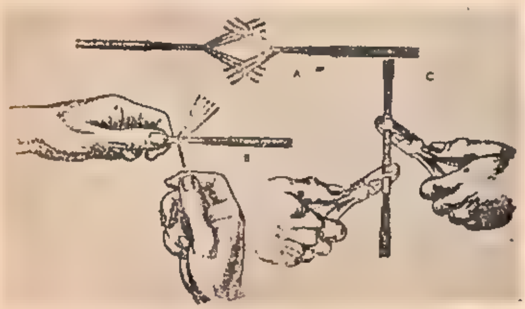
(b)

(a)

finished with two layers of black adhesive tape as shown in Fig. 12.30(b).

Jointing a three strand conductor is shown in Figs. 12.31(a) and (b). The method is similar to what is shown in Figs. 12.30 (a) and (b).

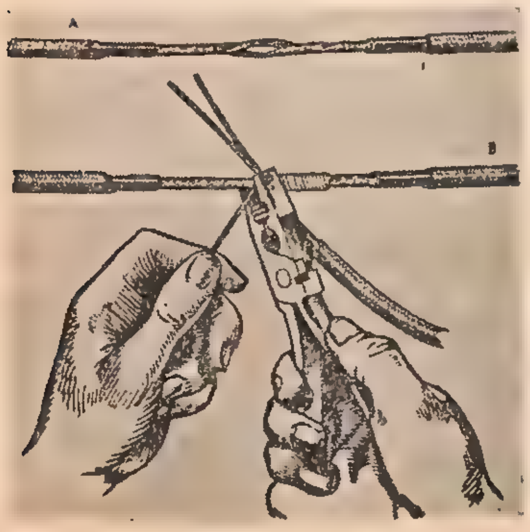
Figs. 12.32(A), (B) and (C) illustrate the stages for making a married joint with a multi-strand conductor. The centre strand is cut away. Wires are twisted, straightened and interlaid. The strands are neatly laid side by side. The joint is finished with two pairs of pliers turning against one another.



Figs. 12.32 (A, B, C)

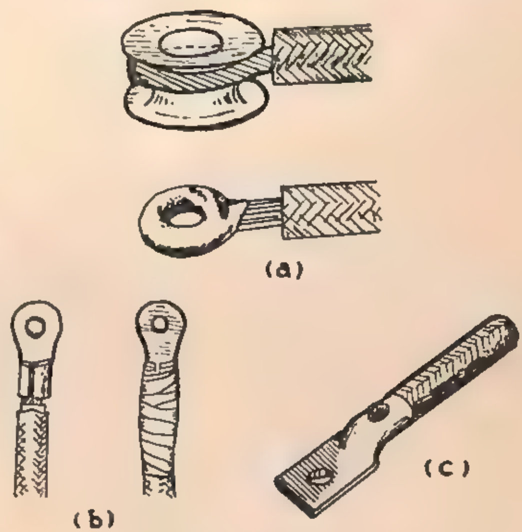
Stages in making a Tee joint may be seen in Figs. 12.33 (A), (B). The centre of

Figs. 12.33 (A and B)



the main cable is opened. The end of the cable to be joined is passed through. The half of the strands are neatly laid round the main cable in one direction and the other half in another direction. The ends are finally trimmed with the plier.

A few cases of splicing are illustrated in Figs. 12.34 (a), (b), (c). Different



Figs. 12.34 (a, b and c)

Fig. 12.35 Electrical fittings

principles are applied in different fields of work.

12.11 Electrical Fittings

For electrical installation some fittings are necessary to complete the various circuits economically and to maintain control over the flow of current.

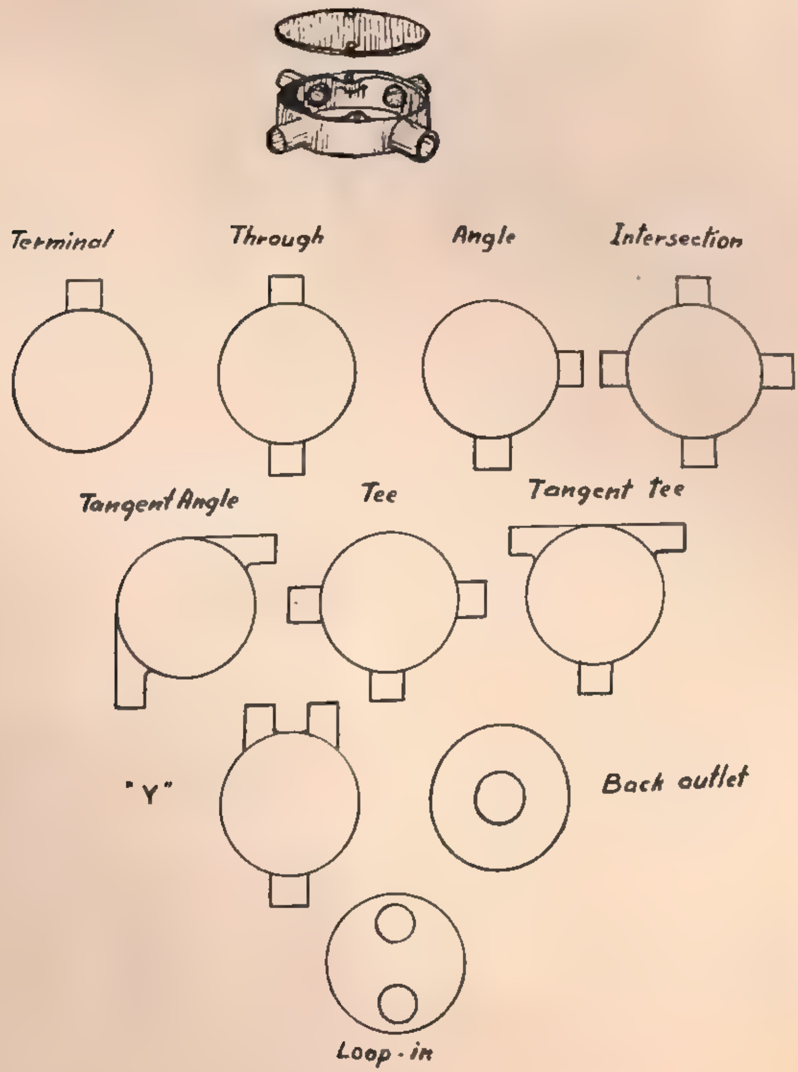
Some of these common fittings in domestic supplies are :

(1) The Main switch, (2) Power meter, (3) Distribution board, (4) Junction box, (5) Switch board, (6) Tumbler switch, (7) Plug and socket, (8) Fan regulator, (9) Ceiling rose, (10) Pendant holder, (11) Wall bracket, (12) Reflector.

Some of these may be seen in Figs. 12.35 and 12.36.

In domestic installation work the total cost is arrived at by multiplying the rate per point and the number of points. The rate per point includes the cost of material

Fig. 12.36 Junction boxes for conduit wiring



and labour. Plug points are taken as half units for estimating the cost.

12.12 Electric Distribution Circuits

The commercial system of distribution of electricity is shown through a few typical circuit diagrams. They show the principles to be followed in the distribution system for different purposes. Figs. 12.37, 12.38, 12.39, 12.40 and 12.41 show the electric circuit diagrams. In all such cases electric regulations are strictly followed.

Fig. 12.40 shows the circuit system for running two generators in parallel. To run one shunt generator parallel to another already feeding the bus-bar, the machine to be switched on is to be speeded up and the field rheostat adjusted until the voltage generated is equal to the bus-bar volt. At this stage the main switch is closed. The load is now distributed in two machines by adjusting their field rheostats.

To disconnect one machine from the bars, its load is to be transferred to the other machine by reducing its field current. When its ammeter indicates zero, the main switch is to be opened and then the engine is shut down.

12.13 Safety Measures

(1) The pliers, screw drivers, knives, etc., used by a worker must have insulated handles.

(2) In the case of high voltage work, the workman should use rubber hand-gloves and stand upon a rubber sheet while at work. In the absence of a rubber sheet, wooden planks or stools may be used.

(3) The workman should switch off the main and take out the fuse bridge of the supply line to make the line dead. The line should be further tested with a pilot lamp to make sure that the correct fuse bridge has been removed.

In the case of a distribution line, in addition to the above mentioned measures, a notice board carrying the instructions "Do not close, Men are working on the line", should be hung. This is very important. It prevents the possibility of a sudden switching on of the main by other people inadvertently.

(4) The leakage of current through short circuit, if any, should be checked before repairing work is started.

(5) The worker working on a live line standing on the insulating board should not be touched by any co-worker who is standing on the ground.

For the safety of the supply lines and of the electrical accessories it should be ensured that

1. cables of proper size are used according to the load in the circuit;
2. the distribution of the load is balanced;
3. there is no leakage of current in the circuit;
4. switch handles, knobs and screws used on the switch board are not shorting or electrically charged;
5. proper fuse wires are used in the fuse bridges;
6. the electric wires are not moist or wet. (moisture spoils the insulation and reduces working life.)
7. in case of electrical accessories like switch gears, motors, etc., the terminals have been properly connected with the respective phases of the supply mains according to the circuit diagrams furnished with the unit;
8. a unit meant for 220 Volts is not connected with 400 Volts supply lines; and

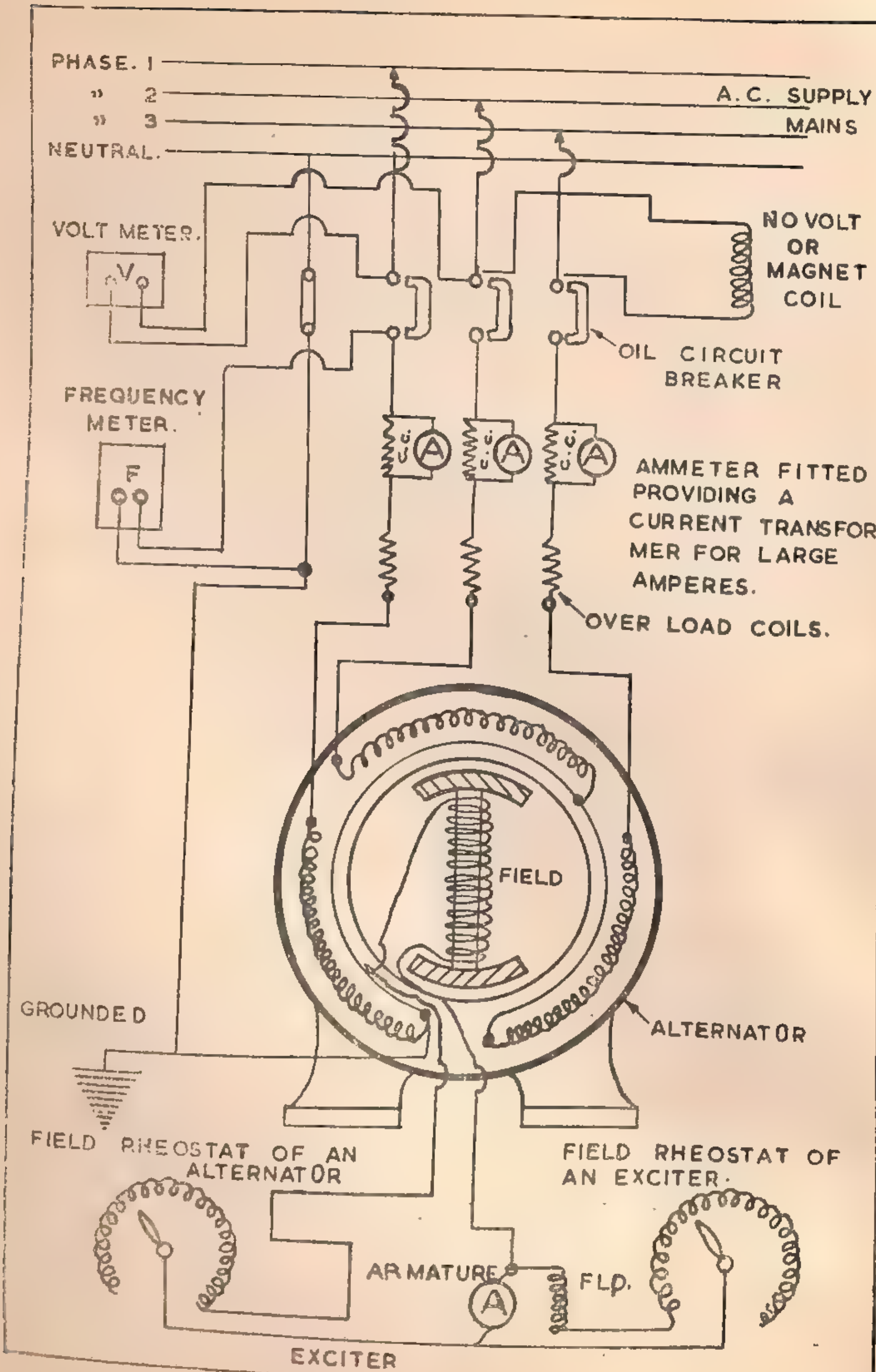

PHASE. 1
" 2
" 3
NEUTRAL.
A.C. SUPPLY MAINS
VOLT METER.
V
NO VOLT OR MAGNET COIL
OIL CIRCUIT BREAKER
FREQUENCY METER.
F
A
AMMETER FITTED PROVIDING A CURRENT TRANSFORMER FOR LARGE AMPERES.
OVER LOAD COILS.
FIELD
GROUNDED
ALTERNATOR
FIELD RHEOSTAT OF AN ALTERNATOR
FIELD RHEOSTAT OF AN EXCITER.
ARMATURE
FLD.
EXCITER

Fig. 12.37

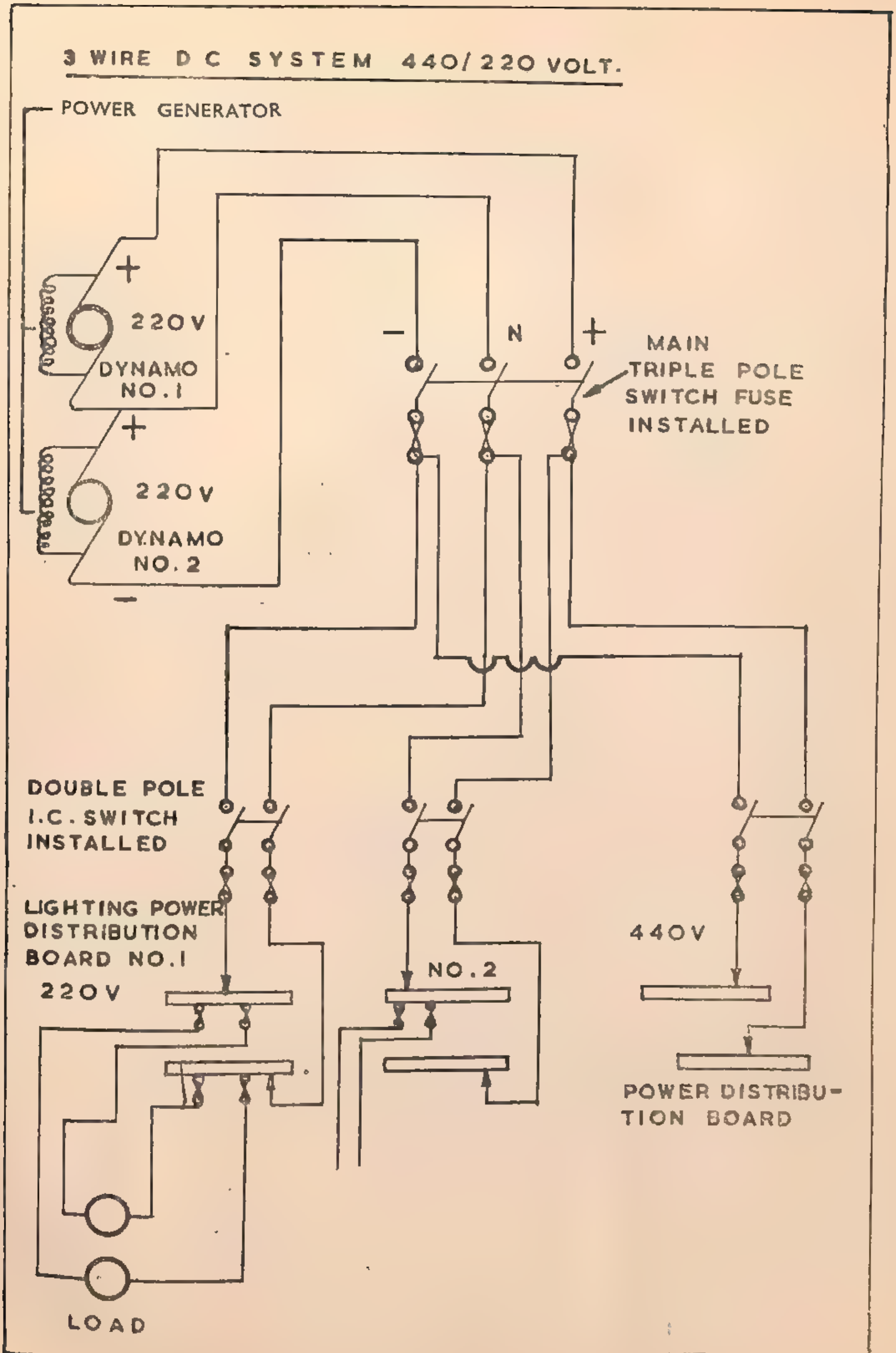
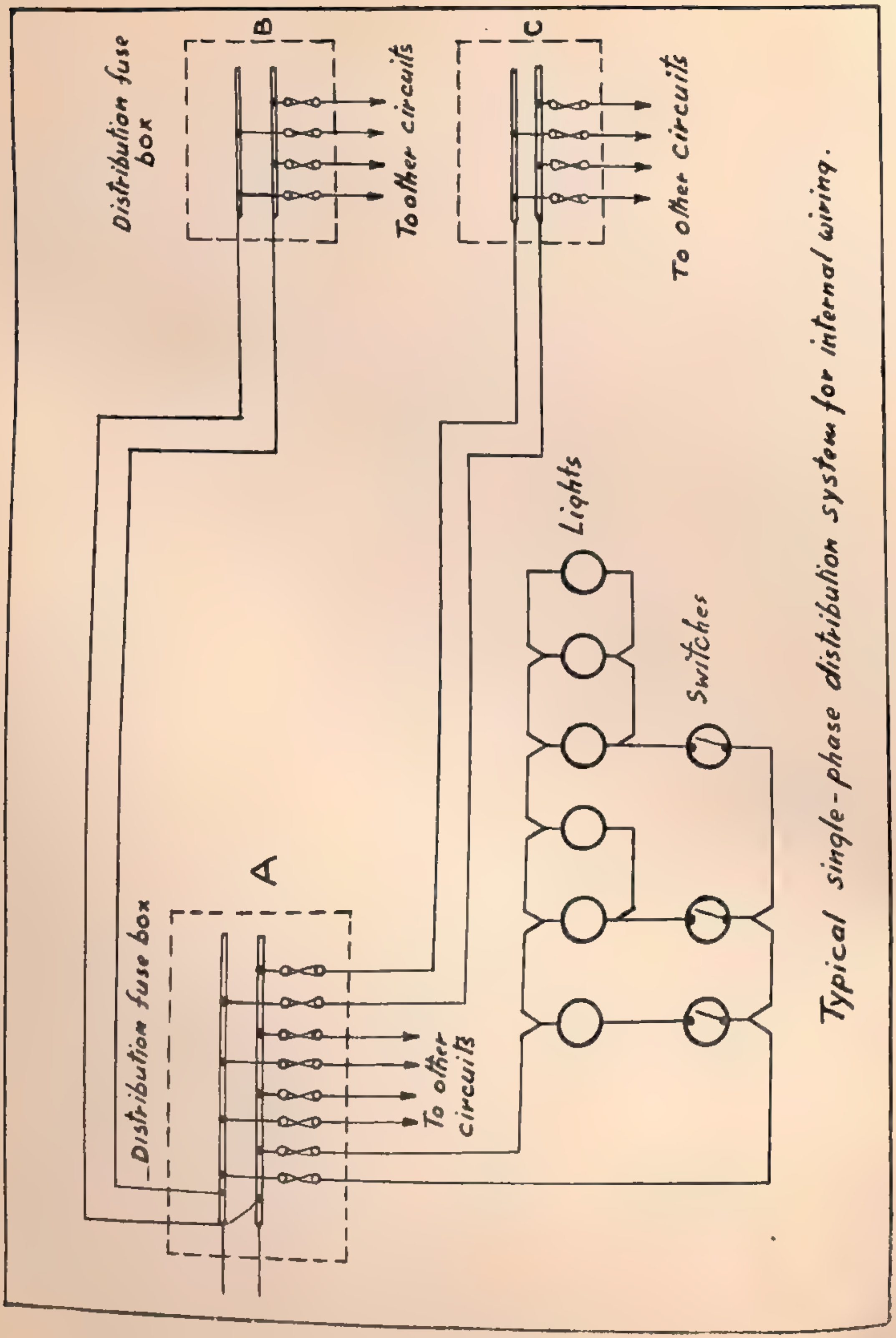

3 WIRE D C SYSTEM 440/220 VOLT.
POWER GENERATOR
+
220V
DYNAMO NO. 1
+
220V
DYNAMO NO. 2
−
−
N
+
MAIN TRIPLE POLE SWITCH FUSE INSTALLED
DOUBLE POLE I.C. SWITCH INSTALLED
LIGHTING POWER DISTRIBUTION BOARD NO. 1
220V
NO. 2
440V
POWER DISTRIBUTION BOARD
LOAD

Fig. 12.38



Typical single-phase distribution system for internal wiring.

Fig. 12.39

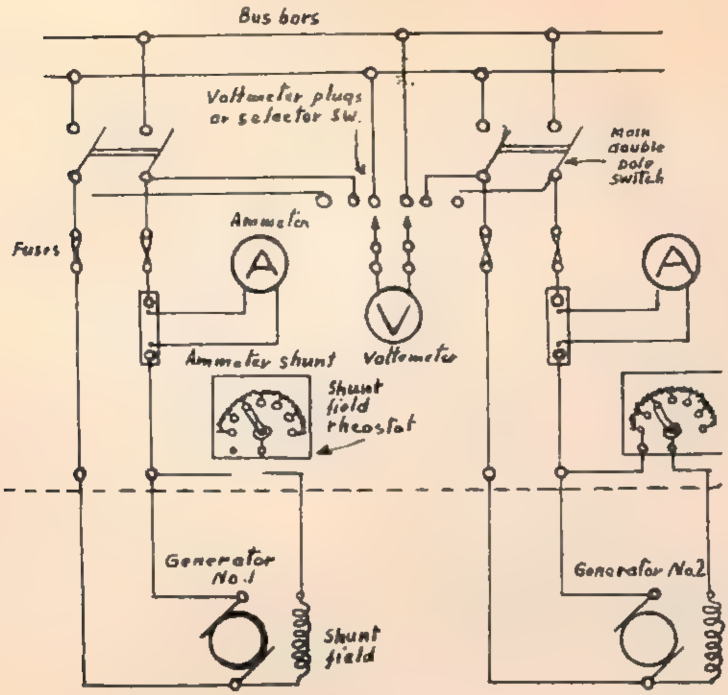


Fig. 12.40

9. the supply voltage does not fluctuate beyond safe limits.

SAFETY FUSES

Every circuit both main and local must be protected by a suitable device which will guard against the flow of excessive current. The simplest and least expensive form of protection is a fuse. This device saves the circuit or the apparatus installed in the circuit from being damaged.

In a distribution circuit all cables have a limited current carrying capacity. If the current exceeds such limit, the cables may be burnt due to overheating. Apart from heavy loss of current, there may be breakout of fire in the building. The above means are therefore adopted to limit the current and to open the circuit whenever heavy current tends to flow.

Fuse is the weakest point deliberately placed in the circuit. Any excess current drawn will cause the fuse blow off first before it does harm to the circuit wiring. This consists of a short length of wire capable of carrying the normally rated current. It is made of an alloy of tin and copper as it melts at a low temperature. This variety works better for small currents but for heavy currents, i.e., above 10 amperes, copper wires are preferred as they have greater carrying capacity for smaller mass.

Below 10 amperes, the quality of fuse wire should be such that with normal working current, it should not get heated, but when the value of current will be about *twice* the rated current flowing through the conductor, the fuse must melt away and open the circuit. This condition determines the size of the fuse wire in any circuit. The following table shows the size of the fuse wire and the rated current.

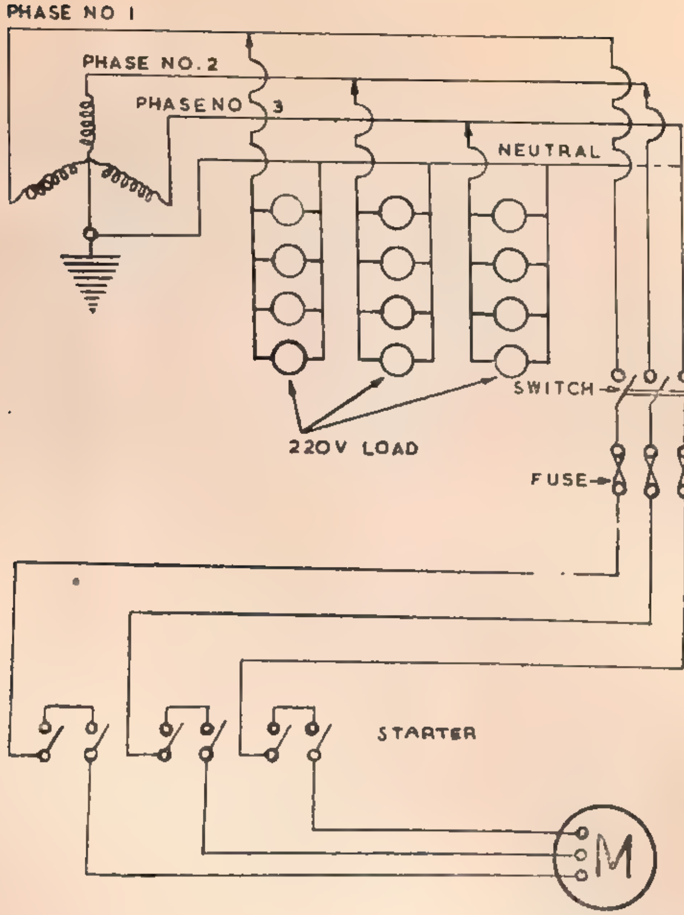


Fig. 12.41 Distribution circuits

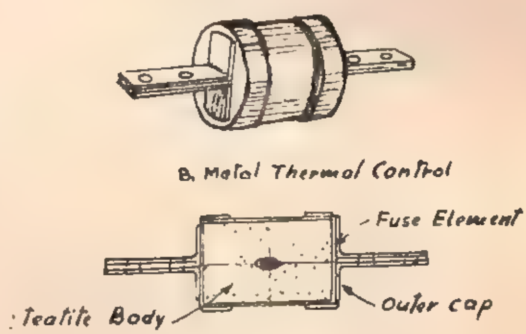


Fig. 12.42 H. R. C. fuse

LEAD TIN ALLOY

Dia. of fuse wire	*Fusing current in ampere*	*Safe working currents (approx.) in ampere*
0.020	3	2
0.028	5	3
0.036	7	5
0.048	10	7
0.064	16	11

FUSE CARRIERS

Fuse wires are mounted on carriers in different ways. The ends of the fuse wires are wrapped round the terminal clips and are held in position by tightening the screws. A simple device is shown in Figs. 12.42, 12.43 and 12.44.

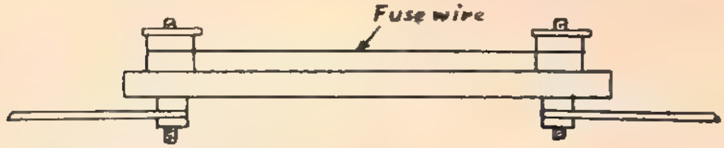


Fig. 12.43 Simple fuse

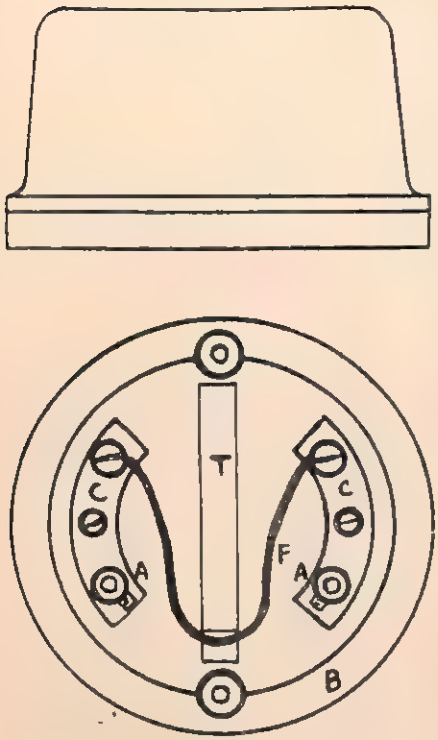


Fig. 12.44 Fuse on porcelain carrier

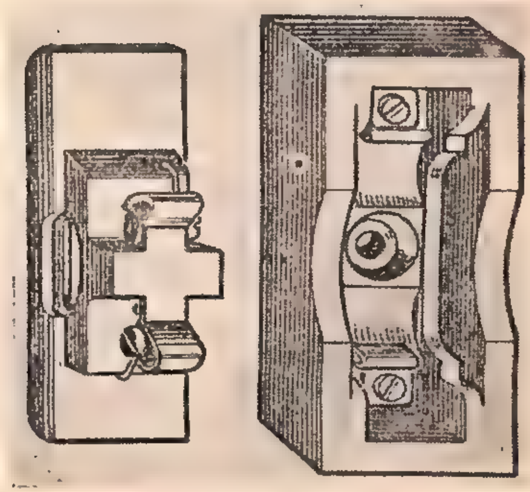


Fig. 12.45 Porcelain fuse bridge

Fig. 12.45 shows a standard fuse bridge used in distribution circuits.

12.14 Electrical Gadgets for Domestic Use

Electricity plays a very important part in domestic service. This includes lighting, heating (both space as well as water), cooking, washing and cleaning, refrigeration, ironing, communication clocks, radio, television and many other gadgets.

(1) Tubular or panel heaters with automatic thermostat control have been made for room heating. Air circulator forces heated air inside the room during winter with the help of a fan. During summer, the fan can be used without the heating element.

(2) Immersion type water heater and Geyser to heat water for bath tubs and kitchen supply.

(3) Electric heater, hot plate, cooking range are units for convenient use in kitchen to replace ovens. Electric kettle, coffee brewers, toasters, etc., are all made for home use.

(4) The laundry equipments include wash boiler, agitator for washing clothes, wringer, drier, and domestic iron, etc.

(5) Cleaning equipment comprises of vacuum cleaner, floor polisher, crockery and dish washers, hair dryer, shaving razors, etc.

(6) Refrigerators, calling bells, clocks, telephones, radio and television are items

of domestic utility for those who have means to pay for them.

(7) Air conditioner uses electric motor to circulate the refrigerant and a fan to force cold air inside the room.

12.15 Common Conventional Signs

Fig. 12.46 shows a few conventional signs used to represent electrical parts in the layout drawing.

12.16 Electrical Regulations

Since careless use of electricity is very dangerous for human life, great caution is taken to avoid accidents. The quality of electrical work is rigorously controlled by electrical regulations. These rules, called the Indian Electricity Rules, clearly prescribe the details of conditions to be fulfilled for any type of electrical installation. A few are given below to explain how these help to maintain a standard of work.

Rule 29. Construction, installation, protection, operation and maintenance of electric supply lines and apparatus :

All electric supply lines and apparatus shall be sufficient in power and size and of sufficient mechanical strength for the work they may be required to do, and, so far as is practicable, shall be constructed, installed, protected, worked and maintained in accordance with the standards of the Indian Standards Institution so as to prevent danger.

Rule 30. Service lines and apparatus on consumer's premises :

(1) The supplier shall ensure that all electric supply lines, wires, fittings and apparatus belonging to him or under his control which are on a consumer's premises are in a safe condition and in all respects fit for supplying energy, and the supplier shall take due precautions to avoid danger arising on such premises from such supply lines, wires, fittings and apparatus.

(2) Service-lines placed by the supplier on the premises of a consumer which are underground or which are accessible shall be so insulated and protected by the supplier as to be secured under all ordinary conditions against electrical, mechanical, chemical or other injury to the insulation.

(3) The consumer shall, as far as circumstances permit, take precautions for the safe custody of the equipment on his premises belonging to the supplier.

(4) The consumer shall also ensure that the installation under his control is maintained in a safe condition.

Rule 31. Cut-out on consumer's premises :

(1) The supplier shall provide a suitable cut-out in each conductor of every service-line other than an earthed or earthed neutral conductor or the earthed external conductor of a concentric cable within a consumer's premises, in an accessible position. Such cut-out shall be contained within an adequately enclosed fire-proof receptacle.

Where more than one consumer is supplied through a common service line each such consumer shall be provided with an independent cut-out at the point of junction to the common service.

(2) The owner of every electric supply line, other than the earthed or earthed neutral conductor of any system or the earthed external conductor of a concentric cable shall protect it by a suitable cut-out.

Rule 34. Accessibility of bare conductors :

Where bare conductors are used in a building, the owner of such conductors shall :

(a) ensure that they are inaccessible;
(b) provide in readily accessible position switches for rendering them dead wherever necessary, and
(c) take such other safety measures as

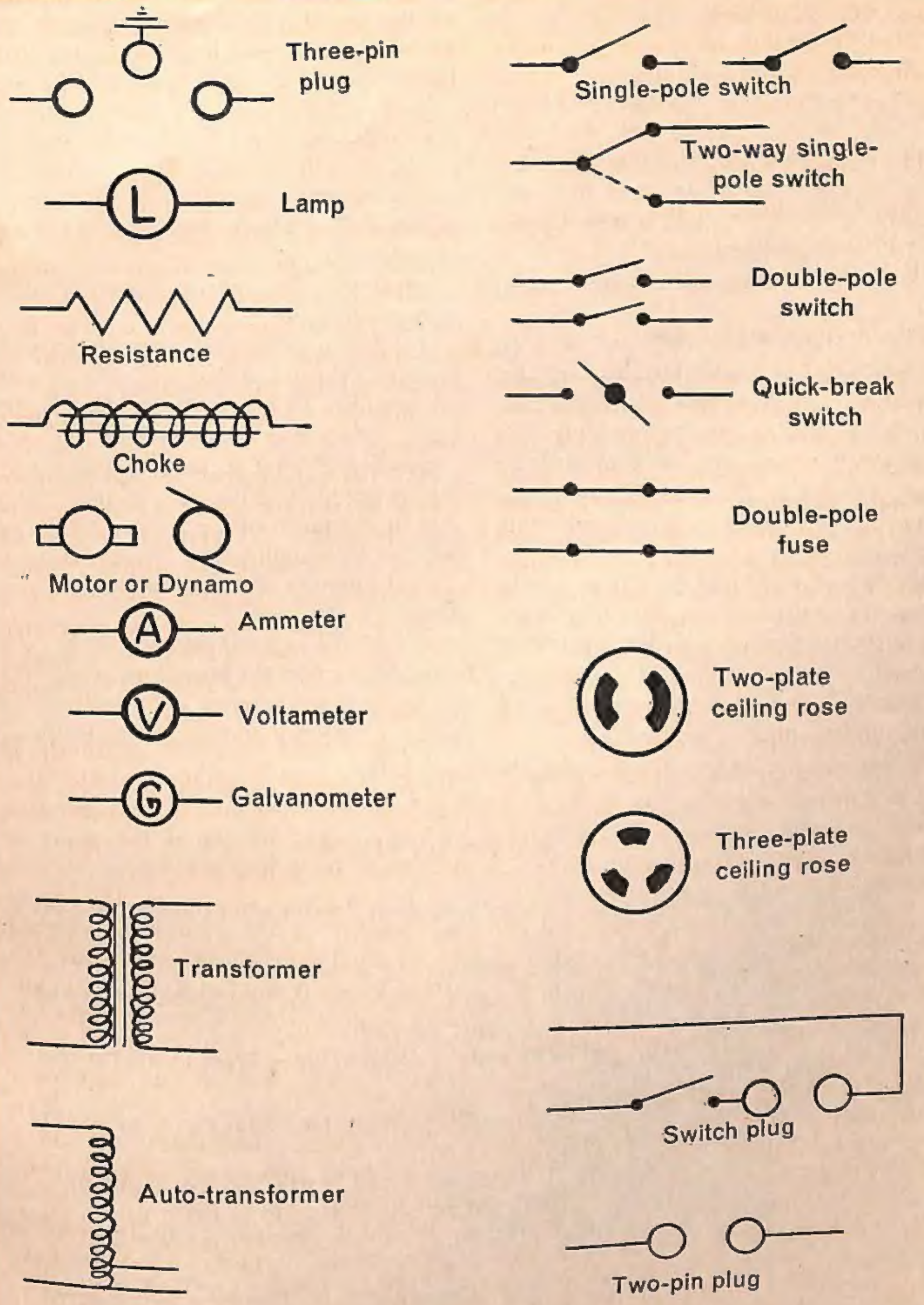

Three-pin plug
Lamp
Resistance
Choke
Motor or Dynamo
Ammeter
Voltameter
Galvanometer
Transformer
Auto-transformer
Single-pole switch
Two-way single-pole switch
Double-pole switch
Quick-break switch
Double-pole fuse
Two-plate ceiling rose
Three-plate ceiling rose
Switch plug
Two-pin plug

Fig. 12.46

are considered necessary by the Inspector.

Rule 35. Caution notices :

The owner of every medium, high and extra-high voltage installation shall affix permanently in a conspicuous position a caution notice in Hindi and the local language of the district and of type approved by the inspector....

Rule 38. Cables for portable or transportable apparatus :

(1) Flexible cables shall not be used for portable or transportable motors, generators, transformers, rectifiers, electric drills, electric sprays, welding sets or any other portable or transportable apparatus unless they are heavily insulated and adequately protected from mechanical injury.

(2) Where the protection is by means of metallic covering, the covering shall be in metallic connection with the frame of any such apparatus and earth.

Rule 46. Periodical inspection and testing of consumer's installation :

Where an installation is already connected to the supply system of the supplier, every such installation shall be periodically inspected and tested at intervals not exceeding five years either by the Inspector or by the supplier as may be directed by the State Government in this behalf or in the case of installations in mines, oil-field and railways, by the Central Government............

Rule 48. Precautions against leakage before connection :

(1) The supplier shall not connect with his works the installation or apparatus on the premises of any applicant for supply unless he is reasonably satisfied that the connection will not at the time of making the connection cause a leakage from that installation or apparatus exceeding one five thousandth part of the maximum current supplies to the applicant's premises.

(2) If the supplier declines to make a connection under the provisions of sub-rule (i) he shall serve upon the applicant a notice in writing stating his reason for so declining.

APPENDIX

Thermal and hydraulic power plants have been developed in different regions as under :

Region 1 : Western Ghats (Kerala, Madras and South Andhra)
Region 2 : Eastern Ghats (North Andhra, South Orissa, East Maharashtra and Central and Southern Madhya Pradesh)
Region 3 : Satpura (Gujarat, Maharashtra, West Madhya Pradesh and extreme South Rajasthan)
Region 4 : Western Himalayas (Jammu & Kashmir, Himachal Pradesh, Panjab, Delhi and Rajasthan)
Region 5 : Central Himalayas (Uttar Pradesh and North Madhya Pradesh)
Region 6 : Eastern Himalayas (Bihar, West Bengal and North Orissa)
Region 7 : Assam Region (Assam, Manipur, Tripura, NEFA and Nagaland)

In Region 1, in addition to Madras city thermal station, important hydro-power stations are located at Pykara, Moyar, Mettur, Papanasam, Periyar, Kundah, and Parambikulam in Madras.

Pallivasal, Sengulam, Pama, Neriamangalam Peniyar are located in Kerala.

Bhadra, Tungabhadra, Sharavati are in Mysore and Nagarjuna Sagar in Andhra South.

In Region 2, the hydro-power station is situated at Mech Kund in Godavari Basin. The important thermal stations are at Khaparkhada and Kobra in Maharashtra.

In Region 3, the important thermal power plant is at Ahmedabad. Other additions are at Dhuvaram in Gujarat and at Satpura.

In Region 4, the locations of hydro-power stations are Jogindernagar, Gangwal, Kolta, Bhakra-Nangal and that of thermal power station in Delhi.

In Region 5, the major thermal stations are those at Kanpur and Hardwarganj.

In Region 6, the important thermal stations are located at Calcutta (Garden Reach and Mulajor), Bandel, Durgapur, Chandrapura, Bokharo, Patratu and Barauni.

The hydro-power stations are located at the dam sites of D.V.C. project, e.g., Tilaya, Panchet and Maithon and at Hirakud.

QUESTIONS

Why is electricity called 'power' ?

What are the different sources of electric power ? At what voltages is current generated ? Name some prominent power-generating stations in different regions of India, indicating whether they are thermal power stations or hydro-power stations.

At what voltage is power transmitted ? What is the advantage of transmitting power at high voltage ? Show in a line sketch the transmission system from a generating station to a substation at the consumer's end.

What are common electrical (a) tools, (b) instruments and (c) material ?

Name a few electrical accessories. What do we understand by insulation ? What qualities does an insulation have ? What purpose is served by it in the construction of electrical machines or in electrical distribution system ? Explain the importance of insulation with examples.

Name some insulating material with the instances where they are suitably used. How is insulation classified? Name some variety of insulators under group of thermoplastics and thermosetting resins. How is insulation dried up in large and small machines or units ? How is insulation tested ? How are D.C. and A.C. motors distinguished ? What are the different types of D.C. and A.C. motors ? What maintenance service is necessary for motors ? What common defects are noticed in D.C. and A.C. motors ? What are the reasons for sparking at the commutator ? How is direction of rotation changed in case of D.C. and A.C. motors ? What are the probable causes for a motor running hot while in use ?

What is the role of the switch gear in electric distribution ? What are the

different varieties of switch gear ? How are they specialized ? What is the function of electric converters ? How do they function ? What are the different types ? Explain with a line sketch the function of any one of them.

What different types of storage cell are made ? What are their specialities ? What are the ingredients used in the wet cell ? What is the capacity of a cell ? What is meant by 'charging a battery' ? To what voltage are the batteries charged and at what voltage are they recharged ?

What principal faults are normally detected in used batteries ? What are the main uses of accumulator cells ? What is the function of a transformer ? How does it help in transmission of electric power ? What is meant by primary circuit and secondary circuit ? How are the primary voltage current and the number of turns of conductor related with the secondary voltage current and the number of turns ? What is a transformer core ? How is it prepared ? What maintenance service is necessary for a transformer ?

What purpose is served by transformer oil ? What speciality should this oil have ? How is a transformer kept cool during use ? What damage will the moisture present in the oil do ? How is oil treated for dehydration ? What is the treatment plant like ? What test is conducted to certify sample of oil as suitable for use ? How is periodical maintenance conducted and how frequently is it done ?

What is the primary object of electrical wiring ? How is cable classified ? How do we specify a cable size ? What are the different types of wiring ? What different electrical fittings are needed for a domestic supply ? State how cable joints are prepared ? Explain with sketches. Show with line diagram the distribution system for wiring a room with two light points and one fan point. How are cables joined in a junction box ? What purpose is served by a fuse ? What different types of fuse are used ? What material are they made of ? What preparation is necessary to run a generator parallel with another ? How are the loads distributed ? How is one of the units switched off firom the load ?

How are different circuits branched off from distribution boxes ? Show with line sketch the distribution system for a 400 volt and 200 volt supply out of 3 phase supply. What safety precautions are taken during work in supply lines ?

Name a few articles of domestic service which use electricity. Draw the conventional signs for Plug Point, Tumbler Switch, Two-way Switch and Choke.